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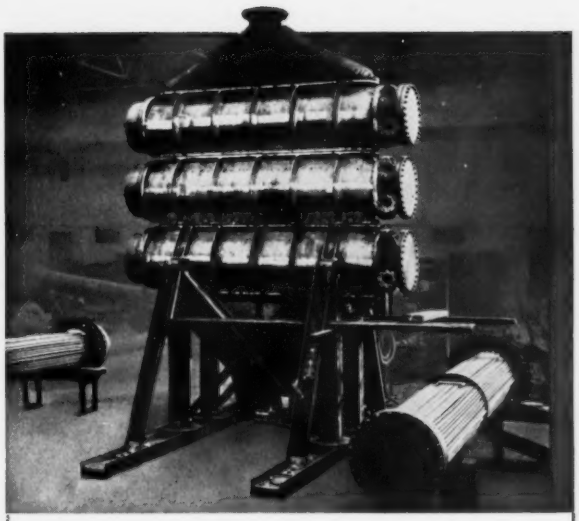

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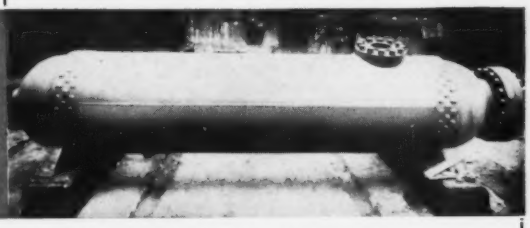

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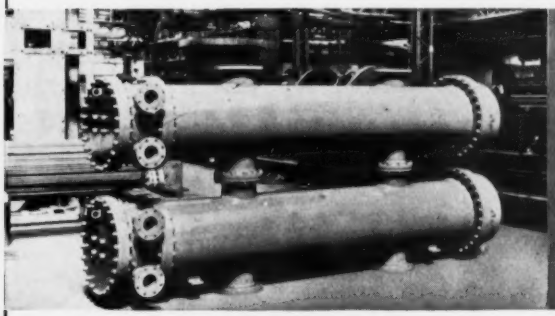

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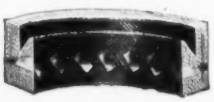

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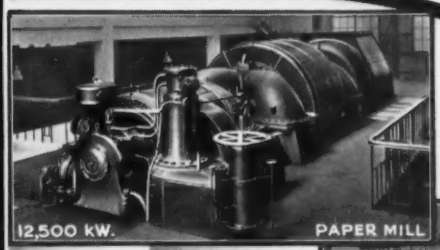

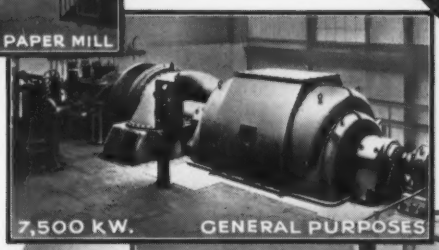

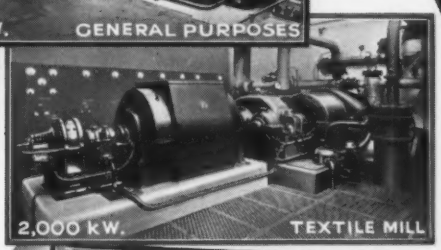

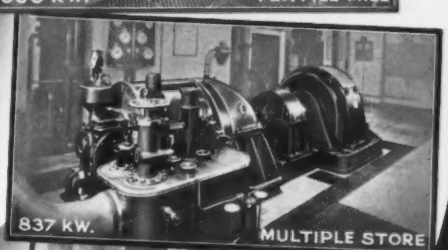

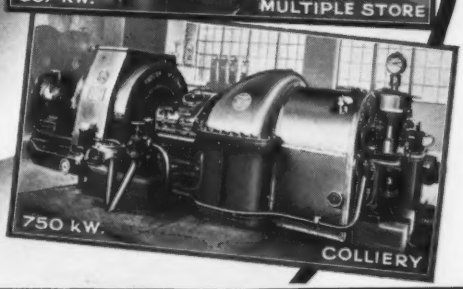

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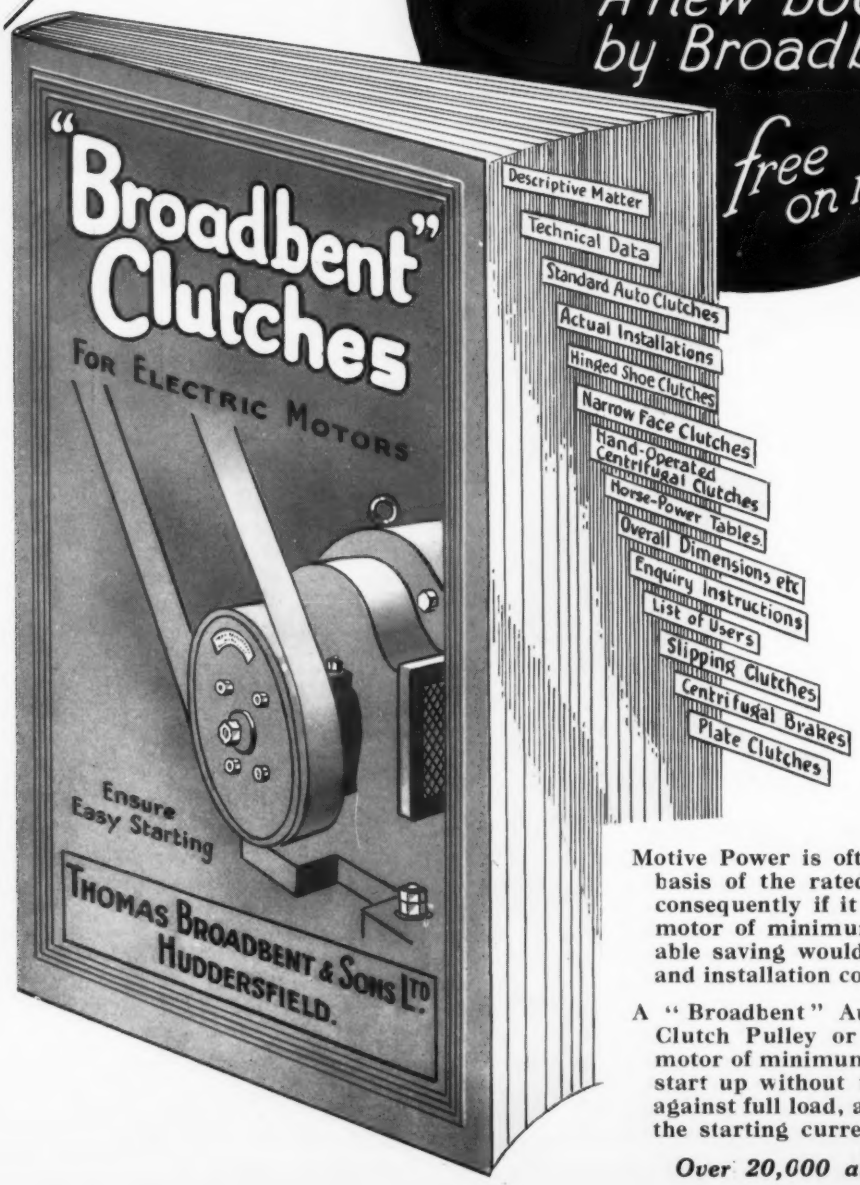

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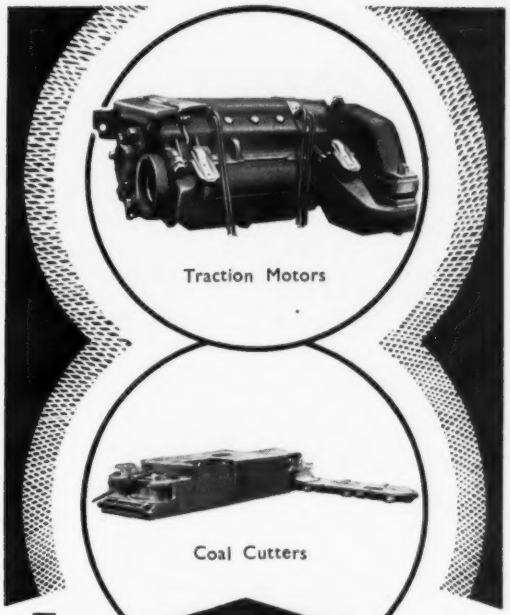

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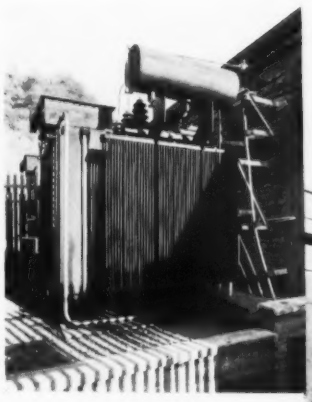

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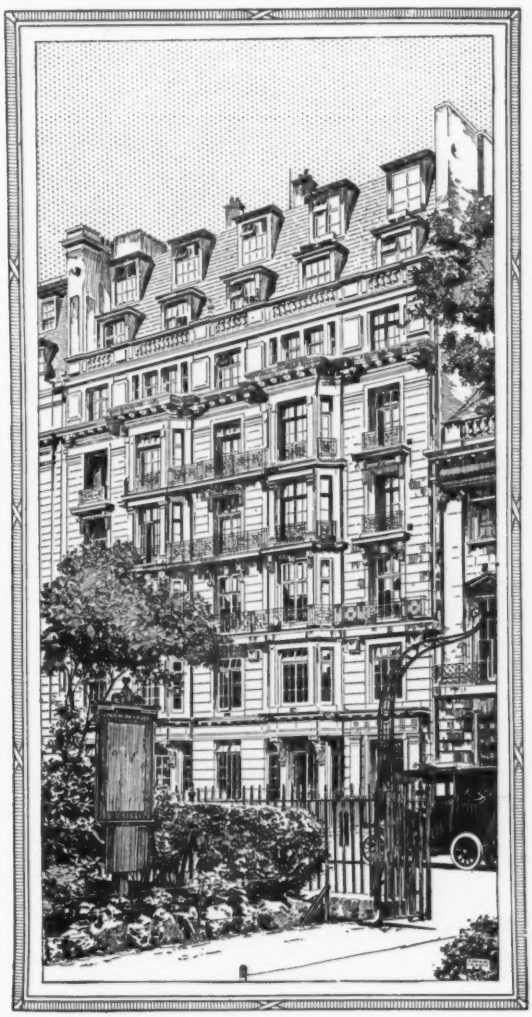

Queen's House from Lincoln's Inn Fields

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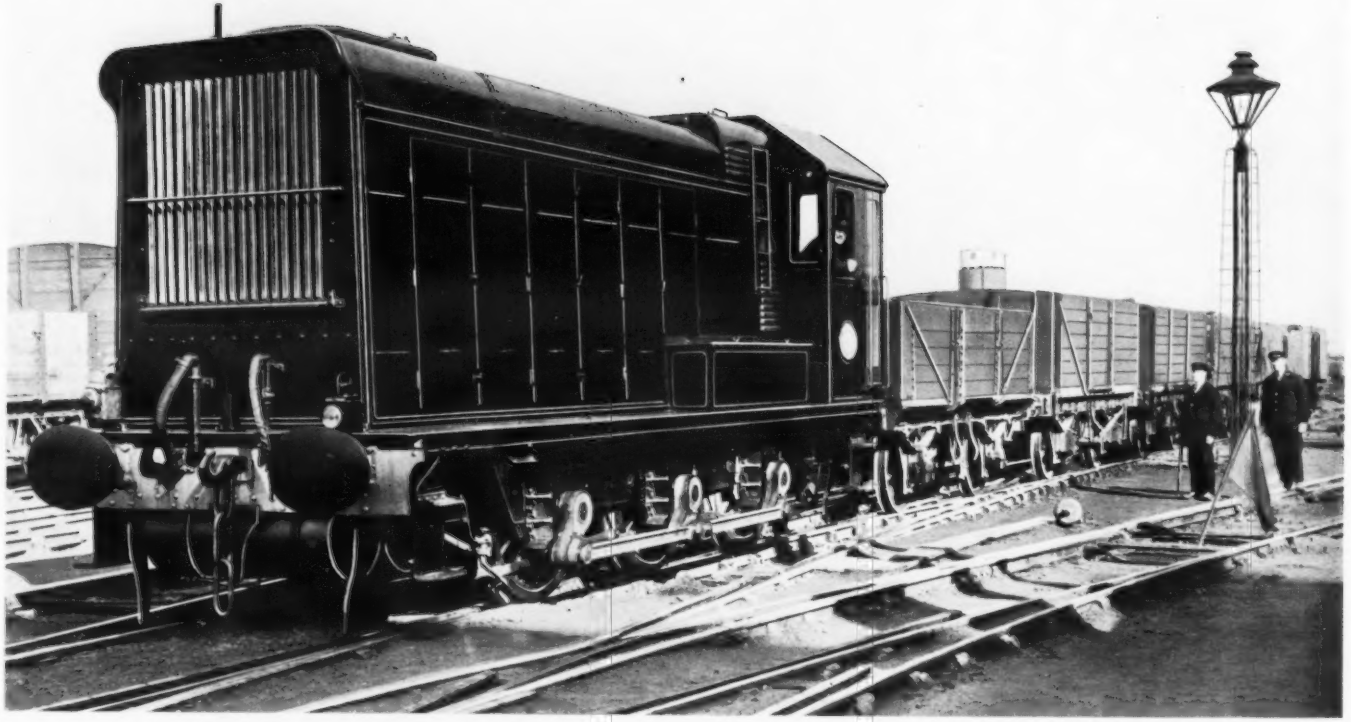

300/350 H.P. Diesel-Electric Locomotive at work in an L.M.S. Railway Shunting Yard.

The English Electric Journal

Vol. VII. No. 4 JANUARY, 1935 One Shilling.

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All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, THE ENGLISH ELECTRIC COMPANY LIMITED, STAFFORD.

EDITORIAL.

The first article in this issue is devoted to a description of some of the electric winding equipments both of the alternating current and Ward Leonard types, recently installed by the Company. Having had over a quarter of a century of experience in the design and manufacture of electric winders for Mines, the Company may claim to be pioneers in the application of this type of electric drive. Mr. J. Kirkwood's article describes the Company's latest practice in this direction, and we would draw our readers' attention to the ingenious automatic accelerating device which can be fitted to the liquid controller on A.C. equipments; this device ensures maximum output without overstrain on the motor and winding gear, and at the same time relieves the driver of considerable manual effort.

The article is illustrated by views of recent installations, together with interesting diagrams showing the B.H.P. outputs that are required on different sizes of winders.

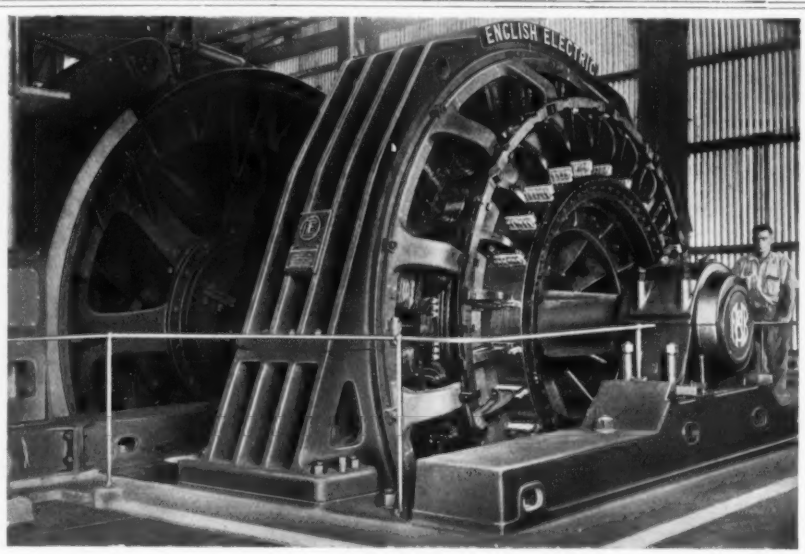
In the article by Mr. L. H. Short entitled "Diesel-electric Shunting Locomotives," are set out the many advantages of the Diesel-electric Locomotive when

used for shunting duty in railway yards where working is on a 24-hour day basis. One of the most striking features of the locomotive described is its "availability" for continuous service. The locomotive can remain in work for practically 24 hours per day, 6½ days per week without shed attention or re-fuelling, thus considerable economies in operation are possible as the steam locomotive without relief units cannot wholly meet the same requirements.

The locomotive illustrated in this article has been operating by the courtesy and co-operation of the London Midland and Scottish Railway Company on its lines since April, 1934, and, as a result of the successful tests carried out, the Company were awarded at the beginning of the year an important contract by the London Midland and Scottish Railway Company for ten similar 350 H.P. Diesel-electric Shunting Locomotives. These will be constructed in collaboration with Messrs. Hawthorn, Leslie and Company, who will supply the mechanical parts comprising frames, superstructures, wheels and axles, the English Electric Company supplying the diesel engines, auxiliary machines and electrical transmission.

The third article gives brief particulars of the 30,000 kW. Turbo-alternator Set installed by the Company early in 1932 at the Thornhill Power Station of the Yorkshire Electric Power Company, together with some details of the excellent performance figures which have been obtained.

The many advantages to be obtained from the centralised control of switchgear in Power Stations are known to all engineers, and, in their article on the "Remote Supervisory Control of Switchgear," Messrs. Newman and Lythall describe the various operations that can be carried out and the apparatus used.



This illustration, just received from South Africa, shows one of the 2940 B.H.P. Winding Motors supplied to Union Corporation Ltd., for the East Geduld Mines Ltd. This installation is described in the article "Electric Winders for Mines," p.84.

Electric Winders for Mines.

By J. KIRKWOOD, B.Sc., A.M.I.E.E.

The application of the electric drive to winding engines in mines was practically unknown 30 years ago, whereas to-day at a conservative estimate considerably over a million horse power is used for this purpose. In this country alone, according to the most recent Report of H.M. Electrical Inspector of Mines, June 30th, 1933, the horse power used for vertical shaft winding engines totalled 153,860 h.p. Of this total, the English Electric Company and its formerly constituent companies have been responsible for about 30 per cent.

At a first glance it might appear that considering the aggregate number of mines at work, the total horse power installed for electric winding is disappointing, but it must be borne in mind that when electricity was first introduced for this service, mining in this country was a well-established industry, and the steam winder had proved itself a very faithful friend to the mining engineer. He was very reluctant to experiment on the principal link in his chain of operations, because if the winding engine failed the pit was shut down, involving severe loss, not only to the colliery owners, but to the men thrown out of employment. Thirty years' experience, however, has proved the reliability of the electrically driven winder, and it is now recognised that not only is it reliable, but it gives the most economical results and lends itself to the incorporation of such safety devices as make it practically fool-proof in operation.

The English Electric Company may claim to be pioneers in the application of electric drive for winding engines, for as far back as 1906—nearly 29 years ago—one of its constituent companies installed a small winder in the North of England for winding men. This winder operates on the Ward Leonard system of control, with flywheel equalisation of the load. It is still giving good service, and only recently a 50-cycle motor was installed to drive the flywheel converter set, this being necessary owing to the change of frequency from 40 to 50 cycles per second.

Since then the Company have installed approximately 150 winders varying in size from 50 to 3,000 b.h.p. continuous rating, the actual peak loads being about twice these figures. A description of some of the most recent winding installations carried out by the English Electric Company will prove of interest.

At the outset it may be stated that whereas the Company are prepared to undertake the Main Contract for Electric Winders, and almost invariably do so, they themselves do not manufacture the mechanical parts such as drums, gearing, etc.; these are supplied by firms who specialise in this class of work. If, however, the customer expresses a preference for mechanical parts made by any particular maker, the Company co-operates fully in order to provide the best possible equipment.

Many systems have been projected and tried out for electric winders, but only two of these have survived, viz. :—

(1) The A.C. System, in which the drum is driven by a 3-phase induction motor.

(2) The Ward Leonard System, in which the drum is driven by a D.C. motor, which receives its power from a separate motor generator or converter set.

A.C. Winders.

The most recent example of an "English Electric" Winder, installed and put into commission, is that at No. 2 Shaft, Hilton Main, owned by the Hilton Main & Holly Bank Collieries, Ltd., near Wolverhampton. This shaft is a new sinking, and the winder has been installed for sinking duty, and will ultimately deal with coal and men. The English Electric Company were the Main Contractors for the winder, the whole of the electrical equipment being manu-

factured at their Stafford Works. Messrs. John Wood & Sons, Wigan, were the sub-contractors for the drum and gearing. An illustration of the winding motor and gearing is shown in Fig. 1.

The winder has been designed for the following ultimate conditions :—

Depth of shaft	1,890 ft.
Duty	Winding coal or men.
Output of coal per hour	100 tons.
Weight of each cage with suspension gear	7,840 lbs.
Decks per cage	Two.
Tubs per deck	Two.
Men per deck	14
Weight of each empty tub	672 lbs.
Weight of coal per tub	1,334 lbs.
Net weight of coal per wind	5,376 lbs.
Alternatively weight of men per wind	4 300 lbs.
Circumference of winding rope	$4\frac{3}{4}$ in. (Locked Coil).
Weight of winding rope	32 lbs. per fathom.
Weight of balance rope	43.44 lbs. per fathom.
Diameter of head gear pulleys	17 ft.
Weight of each pulley	$5\frac{1}{2}$ tons.
Distance between pulleys	5 ft. 9 ins.
Distance between pulley centres and drum centre	135 ft.
Diameter of drum	16 ft.
Width of drum	10 ft.
Time of complete cycle :—	
Winding coal	85 seconds.
Winding men	95 seconds.
Decking time :—	
Coal	10 seconds.
Men	20 seconds.
Net time of each wind	75 seconds.
Time of acceleration	12 seconds.
Time of full speed run	51 seconds.
Time of retardation	12 seconds.
Maximum rope speed	30 ft. per second.
Maximum drum speed	35.6 r.p.m.

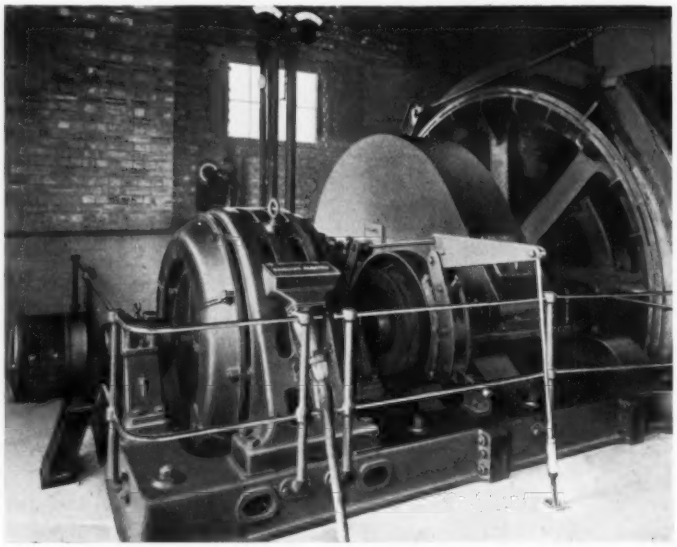


Fig. 1.—600 B.H.P. A.C. Electric Winder installed at the Hilton Main Colliery.

With the usual assumptions for shaft friction, etc., it is estimated that when working to the above conditions, the output of the winding motor when winding coal will be as shown in Fig. 2. To meet these conditions the motor installed has a continuous rating of 600 b.h.p. running at a synchronous speed of 375 r.p.m. on a 3,300-volt, 3-phase, 50-cycle supply. The motor has an overload capacity of 25 per cent. for two hours, or 50 per cent. for one minute, and is capable of dealing with momentary overloads of 100 per cent.

The winder is at present being used for sinking the shaft, and for the sinking period the drum is 9 ft. diameter only, thus reducing the maximum rope speed to 16.9 ft. per second. The loads being dealt with during the sinking period are :—

Weight of dirt	2 tons.
Weight of kibble	2 tons.
Weight of rope per fathom	15 lbs.

The winding motor is of the English Electric Company's LS. reversing type, specially strengthened, with tangential keys, and having

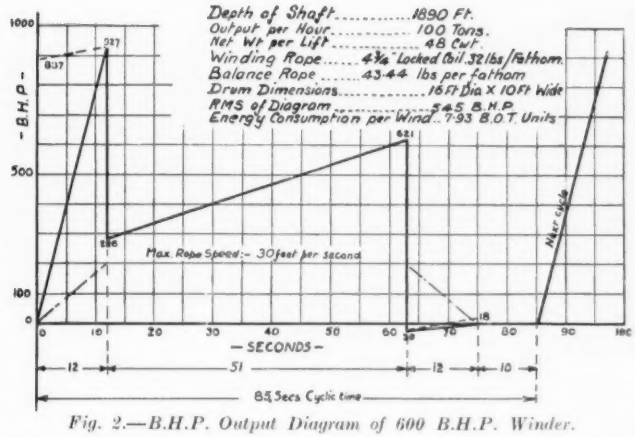


Fig. 2.—B.H.P. Output Diagram of 600 B.H.P. Winder.

special rotor insulation to withstand counter current braking. The motor is of the two-pedestal bearing type mounted on an extension of the bedplate carrying the drum and gearing, and the driving end is coupled to the pinion shaft, which has two bearings, by a Wellman Bibby flexible coupling.

For controlling the incoming supply a mining type draw-out pillar is provided equipped with a triple pole automatic oil-switch, with the usual overload and no-volt features, a voltmeter and a watthourmeter of the unbalanced load type.

An ammeter and a voltmeter, both of the sector pattern, illuminated dial type, are mounted on the depth indicator for the driver's guidance.

The starting of the motor and the regulation of its speed is carried out by means of a liquid regulator in the rotor circuit. This regulator is of the Company's standard LC. type, as illustrated by Fig. 3. It will be noted from the illustration that an internal cooling device, placed in the path of the hot electrolyte, is provided. Cooling water is supplied at the rate of five gallons per horse power dissipated per hour, and the controller has a continuous dissipating capacity of 250 h.p.

The controller is also fitted with an automatic accelerating device, illustrated in Fig. 4. This device relieves the operator of a considerable amount of manual effort and also renders automatic the time of acceleration. The device consists essentially of a small geared slipring induction motor, which supports on the slow-speed shaft a magnetic clutch. When the coils of the clutch are energised the drive is transmitted to a sprocket wheel connected by chain to a driving sprocket wheel in the controller. The clutch is energised by movement of the driver's control lever, and although the control lever may be moved rapidly to the "full on" position, the controller electrodes are moved from the "all out" to the "all in" position, in a time dependent on the setting of the device.

A "follow up" device is also provided so that if the control lever is moved through a portion of its stroke only the winding motor accelerates automatically to the speed corresponding to the position of the lever, and will run at that speed

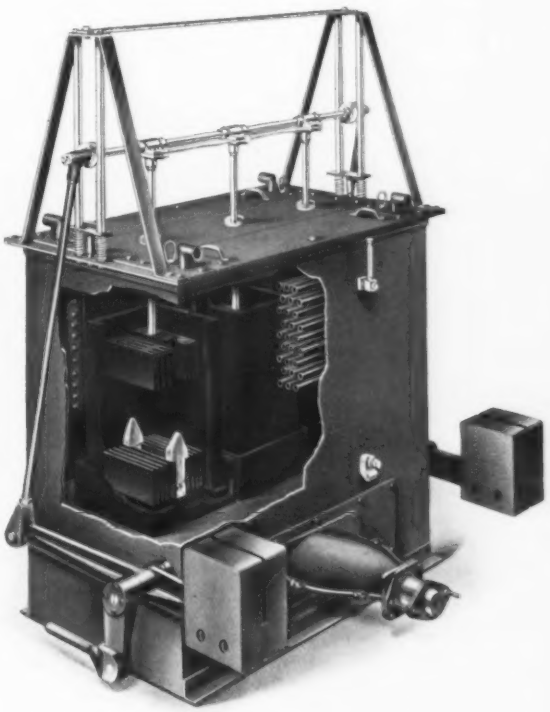


Fig. 3.—"LC" Liquid Regulator, with case broken away to show internal construction.

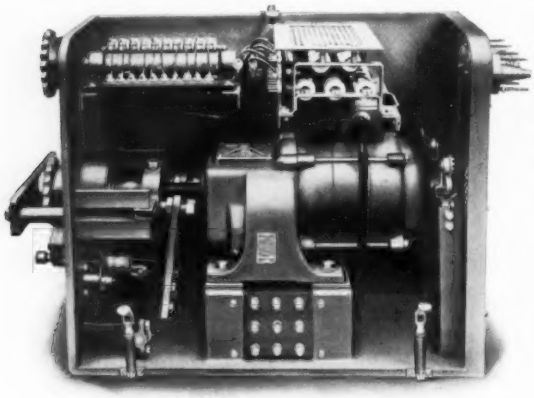


Fig. 4.—Automatic Accelerating Device.

until the lever is again moved, when the speed will be adjusted accordingly. An additional device is provided consisting of a cam-type regulator and a resistance for the rotor of the small slipring driving motor by which the speed of the electrodes can be varied from point to point in order to obtain approximately even acceleration throughout the stroke of the electrodes.

The stator reversing switch is of the air-break magnetically-operated type fitted with blow-out coil, arcing-horns and large arc-shields. Mechanical and electrical interlocks, the latter in the form of arcing relays, are provided so that the set of contactors for one direction of rotation cannot close before the other set is open.

The normal working brakes on the winding drum are also used for emergency braking, and devices are provided to ensure the application of the brakes in the event of failure of supply, overspeed during the full-speed run, failure of the driver to retard at the correct speed as the cages approach bank, and overwind of either cage. Overspeed, overwind and correct retardation are taken care of by a "Lilly" type of overwind and overspeed preventer, and additional overwind limit-switches are also provided on the depth indicator as a second line of defence. "Backing out" switches, interconnected with the overwind limit-switches and the master controller, are provided, so that it is impossible to move a cage in the wrong direction after an overwind. Fig. 5 shows the schematic diagram of connections.

An additional feature on the winder not usual on winders of this size, but specified by the customer, is a solenoid-operated brake on the pinion shaft, capable of bringing the winder to rest in the event of any mechanical failure of the main brakes.

As at present arranged, the drum is 9 ft. diameter × 10 ft. wide for sinking duty, but the drum sides are suitable for the conversion to a 16 ft. diameter drum at a later date, and the additional parts are provided for this purpose. The drum shaft has three bearings, viz., one on each side of the drum and one outside the spur wheel.

The motor drives the drum through single reduction gearing of the machine-cut continuous double-helical type enclosed in a sheet-metal oil-bath gear case.

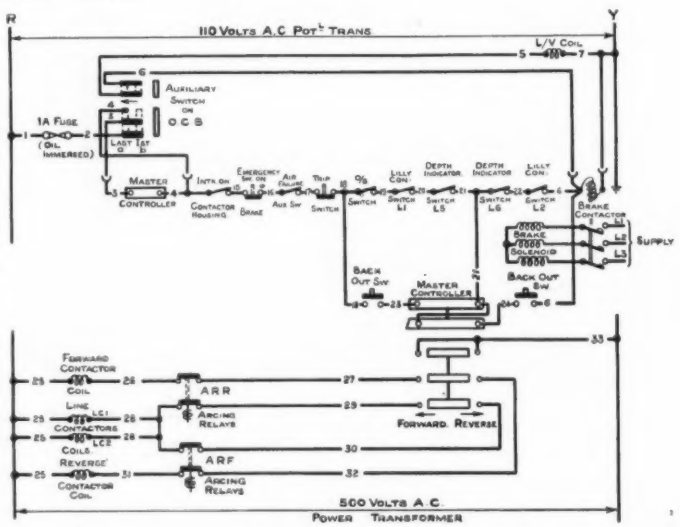


Fig. 5.—Schematic Diagram of A.C. Winder Control Circuit.

A brake-ring is cast on each drum side, and the brakes are of the curved-post type, wood-lined. They are weight operated, the weight being held in the "off" position by a vertical air-brake engine with compensating valve gear and oil cataract cylinder. A small motor-driven air compressor with receiver is provided to supply the necessary compressed air for the brake engine.

A vertical type depth indicator, with double pillars and driven from the drum-shaft to show the position of the cages in the shaft, is provided.

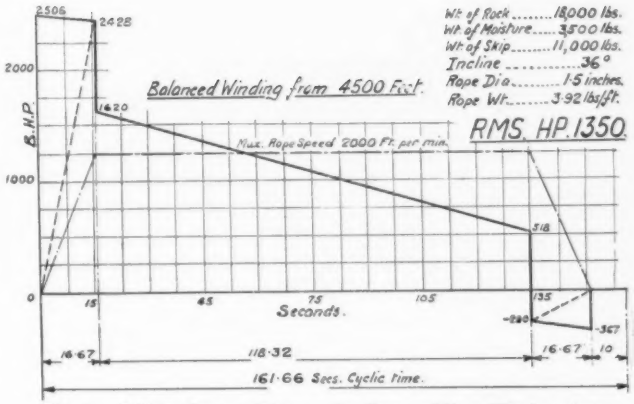


Fig. 7.—B.H.P. Output Diagram for Nourse Mines Winder when winding from 4,500 feet.

This winder has been in operation for about eight months on sinking duty and is giving every satisfaction.

The English Electric Company has also supplied recently electrical equipment for a large A.C. geared winder for Nourse Mines, Ltd., South Africa. The motor is capable of working to the diagrams shown in Figs. 6 and 7, and has a continuous rating of 1,378 b.h.p. at 386 r.p.m. (syn.) on a 1,900/2,200-volt, 3-phase, 51½-cycle supply, and is capable of dealing with overload peaks of 2¼ times normal full load torque. The motor is of the Company's standard LS. type, specially strengthened for reversing winding engine duty. Owing to the large size of the motor, the stator and rotor core laminations are segmental and held in position by double-dovetailed split tapered keys.

A similar equipment has just been supplied for City Deep, Ltd., South Africa. In this case the motor has a continuous rating of 1,270 b.h.p. at 386 r.p.m. (syn.) on a 1,900/2,200-volt, 3-phase, 51½-cycle supply, with normal peaks of 2,208 b.h.p.

Two smaller A.C. geared winders have just been supplied for the New Consolidated Gold Fields, Ltd. One is for the Taquah & Abosso Mines, Ltd., West Africa, and is to deal with a net weight of 3 tons per lift from an inclined shaft 1,900 ft. long at 40 deg. to the horizontal, the maximum rope speed being 1,000 ft. per min., and will be capable of winding an unbalanced loaded skip infrequently. For this duty a motor is being installed having a continuous rating of 250 b.h.p. at 750 r.p.m. (syn.) wound for a supply current of 3,300 volts, 3-phase, 50 cycles. The electrical equipment is generally similar to that described for the Hilton Main Winder. The mechanical parts, which are being manufactured by the Usk-side Engineering Co., comprise two drums each 7 ft. 6 ins. diameter × 4 ft. 3 ins. wide, both drums being gunmetal bushed to run loose on the drum-shaft. The drums are connected to the shaft by means of two cast-steel multi-tooth clutches arranged with screw down operating gear

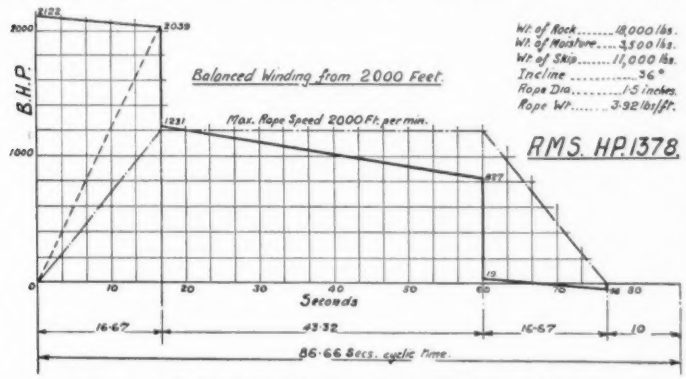


Fig. 6.—B.H.P. Output Diagram for Nourse Mines Winder when winding from 2,000 feet.

and fully interlocked with the brake mechanism so that neither drum can be declutched unless its brake is full on, and the brake cannot be taken off unless the clutch is in. The drive from the motor is carried out by double-reduction gearing, the first reduction consisting of double-helical teeth and the second of straight machine-cut teeth. The brakes are of the curved-post type, operated by two oil-pressure brake engines.

The other winder for West Africa is for the Ariston Gold Mines (1929), Ltd. In this case Messrs. Robey & Co. are the Main Contractors, and the English Electric Company are the sub-contractors for the electrical equipment. The winder is to lift a net load of 3,360 lbs. from a vertical depth of 1,000 ft. at a maximum rope speed of 500 ft. per min., and will be capable of dealing with an unbalanced loaded skip infrequently. The motor is rated at 120 b.h.p. continuously on a 3,300-volt, 3-phase, 50-cycle supply. The winder is of the double-drum type, each drum being 6 ft. diameter × 2 ft. 3 ins. wide, the drive from the motor being through double reduction machine-cut gearing. Each drum is loose on the shaft and fitted with a multi-tooth clutch, the clutches being suitably interlocked with the brakes to ensure correct sequence of operation. In this case the brakes are foot operated, and, in addition, a screw down gear is provided. In other respects the winder is similar to those already described.

Ward Leonard Winders.

On winders with Ward Leonard Control a direct-current motor is used to drive the drums. On plants of small and medium size the drive is almost invariably through gearing, but on large equipments the common practice is to couple the motor direct to the drum. There is, however, a growing tendency to use gearing even on large winders.

The Ward Leonard System is based on the fact that the speed of a separately excited D.C. motor is directly proportional to the voltage applied to the armature. Such a motor can, therefore, be made to assume any desired speed and any direction of rotation according to the value and direction of the voltage applied to the armature.

The D.C. power is obtained from a separately excited generator, which is driven at constant speed by a motor, generally of the A.C. slipring induction type—although not necessarily so—which is connected to the supply mains. These two machines are coupled together and the shaft extended at one end to carry a small D.C. generator, which supplies the excitation current for the fields of the winding motor and generator. The combination of these three coupled machines mounted on a common bedplate is known as the converter set.

By means of a regulator, which may be of the face plate or contactor type, the field of the generator and consequently its voltage can be varied from 0 to $\pm$ a maximum ; consequently, the speed of the winding motor to which this voltage is applied can also be varied from 0 to $\pm$ a maximum.

The principal feature of the control is that the speed and direction of rotation of the winding motors are determined solely by the regulator, or, in other words, by the position of the driver's control lever. For all practical purposes this holds true whatever the load in the cage may be, and whether the load is being raised or lowered. When the control lever is in a running position, if it be moved towards the " off " position, a strong electrical braking effect is obtained as the motor then acts as a generator, and returns energy through the converter set to the line. The same electrical braking effect is obtained when lowering loads. A very slight movement of the lever from the " off " position gives creeping speeds when such are required.

During the acceleration and retardation periods the movement of the control lever is regulated by cam gear. Two cam wheels are provided, one for each cage, driven from the drum through gearing, so that the wheels make nearly one complete revolution per wind. Each wheel has two cams, one for acceleration and one for retardation. When starting the wind, the control lever can only be moved from its mid-position at a rate determined by the shape of the cams, which shape is designed to give the pre-determined rate of acceleration, and this rate cannot be exceeded. As the cage or skip approaches bank, and retardation should

begin, if the driver has not already brought back his lever the retardation cam gradually forces the lever back to the "off" position. Acceleration, retardation and speed of wind are within the driver's control provided he does not attempt to exceed the limits for which the cams are designed.

In the event of overspeed, electric braking automatically takes place. The winding motor will act as a generator and supply power to the generator, which will then act as a motor driving the converter set above synchronous speed, causing the induction motor to act as an asynchronous generator and return power to the line. Should the speed of the set exceed a pre-determined maximum, a centrifugal device either driven from the drum or from the converter set opens the circuit of a solenoid brake-magnet and applies the emergency brakes.

With the Ward Leonard System it is also possible to limit without difficulty the maximum speed when winding men. To do this a variable resistance is inserted in the field of the generator, limiting the excitation to any desired value, and consequently limiting the value of the generator voltage which controls the speed of the winding motor.

The emergency devices are, in general, similar to those on an A.C. winder, except that on English Electric Ward Leonard Winders controlled electric braking is utilised to assist in bringing the winder to rest. This is brought about by a drum-type multi-point switch, actuated by a falling weight, which is controlled either by the ordinary emergency trip-gear or by a solenoid. This switch is in the field circuit of the variable voltage generator and controls the degree of regenerative braking by regulating the rate of weakening of the generator field while it leaves the motor field at its full value, thus maintaining regenerative braking until the motor comes practically to rest.

Electric braking in this way operates almost immediately after the emergency occurs, and as the application of the mechanical brakes is known to have an appreciable time lag, the winder will have started to slow down before the mechanical brakes are applied; consequently, their application can safely overlap with regenerative braking without causing excessive stresses in the ropes.

In many Ward Leonard Systems, regenerative braking in emergency is definitely discouraged by opening the exciter field and causing the winding motor field and the generator field to die down simultaneously. Emergency braking in such cases is left entirely to the mechanical brakes. This seems fundamentally wrong when effective regenerative braking is available to assist in bringing the winder to rest. Further, cases have been known of mechanical brakes failing, and in such cases effective regenerative braking, which would bring the winder practically to a creeping speed, and is always in action as long as there is movement of the winder, would prove invaluable.

The English Electric Company were among the first to advocate the use of compensating windings on both winding motor and generator on Ward Leonard Winders, and it is their standard practice to do this on all winders of this type. A compensated motor has an advantage over an uncompensated one, in that the latter loses a considerable amount of flux on overloads due to armature reaction. Peak loads of twice the normal output are quite usual on winders, and the uncompensated motor will probably require about two and a-half times full-load current to give twice full-load torque. This gives rise to excessive losses and low efficiency in operation. It also causes undue heating of the machines—motor and generator—and may cause sparking on the motor, as it is hardly possible to avoid saturation of the commutation poles of an uncompensated machine at such heavy overloads. On compensated machines, on the other hand, the current is strictly proportional to the torque for any overload, and there is no difficulty in avoiding saturation of the commutation poles up to three times normal torque, which is well beyond the demands of a winding motor. A combination of a compensated generator with an uncompensated motor which is sometimes advocated is undesirable, because when a heavy load comes on, the motor loses flux and its back E.M.F. falls, whereas the E.M.F. of the compensated generator is maintained and thus tends to cause current surges.

An improvement to prevent creepage, which is covered by an English Electric Company's patent,

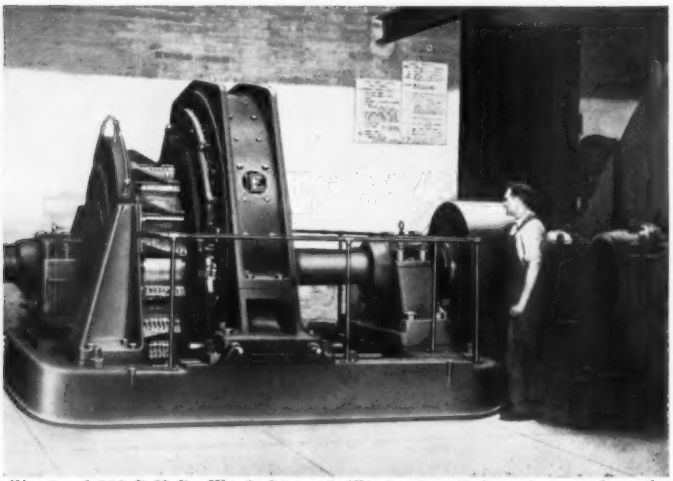


Fig. 8.—1,805 B.H.P. Ward Leonard Winder installed underground at the Crown Mines 15a shaft.

consists in a small displacement of the compensating winding of a generator in a direction opposite to the rotation. This gives the effect of a small negative series winding and prevents the generator from building up a considerable current with zero field, and consequently tends to prevent creeping when the control lever is in the "off" position.

The Company has supplied many notable Ward Leonard Winders in the past; these include, amongst others, six for the Powell Duffryn Steam Coal Co., for Britannia, Llantrisant and Windsor Collieries, two for Taff Merthyr Steam Coal Co., two for Hulton Colliery, one for Pearson & Dorman Long's for Snowdown Colliery, and one each for the Nundydroog Co. and the Mysore Gold Mining Co., India.

During the past year four large Ward Leonard equipments have been shipped to South Africa, two of these to the order of Union Corporation Ltd., for East Geduld Mines, and two to the order of the Central Mining and Investment Corporation Ltd., for Crown Mines Ltd. The latter two are for underground use, and Fig. 8 shows one of the winding motors supplied. This motor has a continuous rating of 1,805 b.h.p. at 200 r.p.m., and drives the drum through single reduction double-helical gearing. The illustration shows the motor installed on site. It will be noted that the brush gear is mounted on separate brackets so as to permit the magnet frame to be moved without disturbing the brushes, and the shaft is made specially long to permit the frame to be moved along the bedplate, in order to facilitate examination and repair of the armature should this be ever necessary.

A further order has now been received from Union Corporation for two large Ward Leonard Winders for Van Dyk Consolidated Mines, Ltd., and also from the Coniaurum Mines, Ltd., for one Ward Leonard equipment.

The two equipments for East Geduld are for the rock hoists at Nos. 1 and 2 shafts respectively. The actual shaft depths and load conditions differ slightly at the two shafts, but the equipments are duplicate in every respect and designed to work to the conditions obtaining at No. 2 shaft, which are as follows :—

Maximum winding depth	...	4,360 ft.
Net weight of ore per wind		12,720 lbs.
Weight of each skip...	...	9,230 lbs.
Diameter of winding rope	...	$1\frac{3}{4}$ inches
Weight of rope per foot	...	5.425 lbs.
Number of winds per hour	...	30.7.
Time of winding cycle	...	117.2 seconds

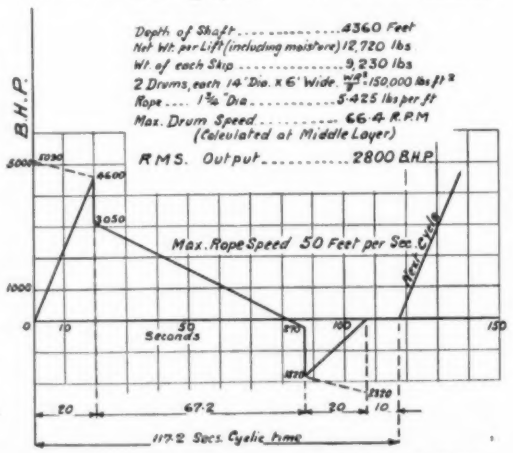


Fig. 9.—B.H.P. Output Diagram of 2,940 H.P. Ward Leonard Winder when working balanced.

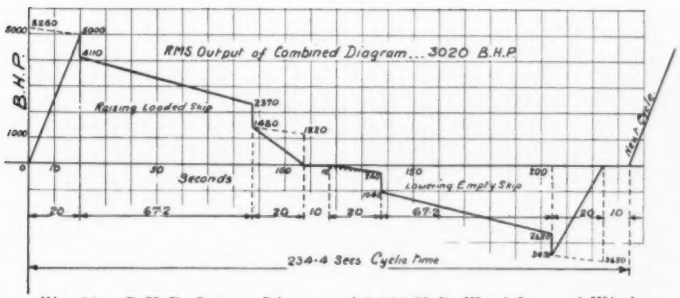


Fig. 10.—B.H.P. Output Diagram of 2,940 H.P. Ward Leonard Winder when working unbalanced.

Interval between winds	...	10 seconds
Time of acceleration	...	20 seconds
Time of full speed run	...	67.2 seconds
Time of retardation	...	20 seconds
Average maximum rope speed		50 ft. per sec.
Maximum drum and motor speed	...	66.4 r.p.m.
Type of drum	...	Bi-cylindrical
Diameter of each drum	...	14 ft.
Width of each drum	...	6 ft.

Normally winding is carried out with the skips balanced, but the equipment is amply rated to lift an unbalanced loaded cage infrequently. The curves shown in Figs. 9 and 10 show the estimated b.h.p. outputs when working balanced and unbalanced respectively.

The ratings of the winding motor and converter set for each equipment are as follows :—

Continuous rating of winding motor	...	2,940 b.h.p.
Full load speed of winding motor	...	66.4 r.p.m.
Continuous rating of generator at 675 volts	...	2,300 kW.
Continuous rating of exciter		30 kW.
Continuous rating of A.C. driving motor	...	2,000 b.h.p.
Speed of converter set	...	500 r.p.m. (syn.)
Power supply	...	2,000 volts, 3-ph., 50 cycles

The winder at No. 1 shaft has actually to deal with a net load of 16,960 lbs. from 3,214 ft. at a maximum rope speed of 39 ft. per sec. This slower normal running speed is obtained by the insertion of a permanent resistance in the field of the generator of No. 1 Equipment, which reduces the maximum voltage to 510 volts. The winding motors and generators are of the Company's CS. type, with cast-steel spiders and magnet frames. The winding motors are specially strengthened for the arduous duties called for in winding engine practice, the spider being secured to the shaft by tangential keys and the armature core plates secured to the spider by special split dove-tailed keys. The winding motors are amongst the largest self-ventilated motors in the world on winding engine duty. Each armature weighs approximately 25 tons, and each magnet frame 38½ tons, the total weight of each machine being approximately 63½ tons.

Fig. 11 shows one half of the winding motor magnet frame and gives a very good idea of its size and robust construction.

The driving-motor for the converter set is of the LS. slipring induction type with brush-lifting and short-circuiting device.

For starting up the converter sets, liquid starters of sufficient capacity to allow starting on light load three times in succession have been provided. The starter is suitably interlocked with the main oil-switch, and the brush-lifting and short-circuiting gear to ensure correct sequence in starting.

For the control of the stator circuit of the converter motor a sheet-steel cubicle has been provided equipped with a 600 amp. triple-pole oil circuit-breaker having a rupturing capacity of 100,000 kVA. and fitted with a no-volt and three overload air-vane time lag releases. The usual measuring instruments, such as ammeters, voltmeter and watthourmeter, are also fitted on the cubicle.

Fig. 12 illustrates the schematic diagram of connections of the control gear and shows clearly how the various emergency devices control the circuit of the brake solenoid which operates the emergency brakes.

Safety devices are fitted to apply the brakes in the event of overwind, overspeed, overload, failure of winding motor field, and failure of A.C.

supply voltage. Cams are also provided driven from the drums to ensure that the pre-determined rate of acceleration shall not be exceeded, and that retardation takes place at a pre-determined position when the skips are approaching bank.

All the necessary indicating instruments for the driver's use are mounted on a column on the operating platform, including three coloured lamps, each indicating a particular function of the control apparatus. A yellow lamp indicates when the controller is in the "off" position, a red lamp when the motor field weakening resistance is in circuit, and a green lamp when the emergency brake-solenoid is energised and the emergency brakes are "off."

The main controller which regulates the field of the variable voltage generator is of the 100-way face plate reversing type, fitted with combined "suicide" and "off" position contacts. All contacts are mounted on an insulated base, and are fitted with renewable faces of hard drawn copper, which can be replaced individually.

The brush arm is mounted on the operating spindle, from which it is suitably insulated. The brushes are clamped directly on this arm, and are of a design which allows the contacts to follow up whilst maintaining constant brush pressure. Each brush has two independently controlled contact makers, which prevent interruption of the circuit should one fail. The spindle is supported by two ball bearings, which ensure accurate alignment and ease of operation. The face plate and spindle are mounted on a wrought-iron framework, which houses the controller resistances, the latter consisting of copper-nickel alloy wire wound over grooved porcelain insulators. The insulators are mounted on light iron frames and supported very rigidly by insulated bolts.

The connections between the face plate contacts and controller resistances consist of bare copper, carefully spaced and rigidly supported to prevent short circuits due to vibration or sagging.

It will be remembered that the variable voltage generator is fitted with displaced compensating windings on the pole faces, which has the same effect as of negative series turns and tends to destroy the residual magnetism in the field when the controller is in the "off" position, and so prevents creeping. In this connection a second line of defence is provided in the form of the "suicide" contacts on the main controller, which connect the variable voltage generator field across its own armature, so that the voltage generated by the residual magnetism is used to produce a flux opposing the residual magnetism and so destroy it; hence the term "suicide." This is a most important feature on Ward Leonard winders.

Overload protection is provided by an overload relay mounted astride the connections between the generator and winding motor armatures, the relay being arranged to trip the brake-solenoid contactor and so apply the emergency brake in the event of overload. This is preferable to having a main circuit-breaker, as it ensures the continuity of the circuit and so permits of regenerative braking in emergency. An intermediate overload relay is also provided, the operating coil of which is shunted across the compensating and commutation-pole winding of the generator.

There is one occasion on which regeneration is impossible, and that is when the main supply

Fig. 11.—Top half of Magnet Frame of 2,948 B.H.P. Winding Motor.

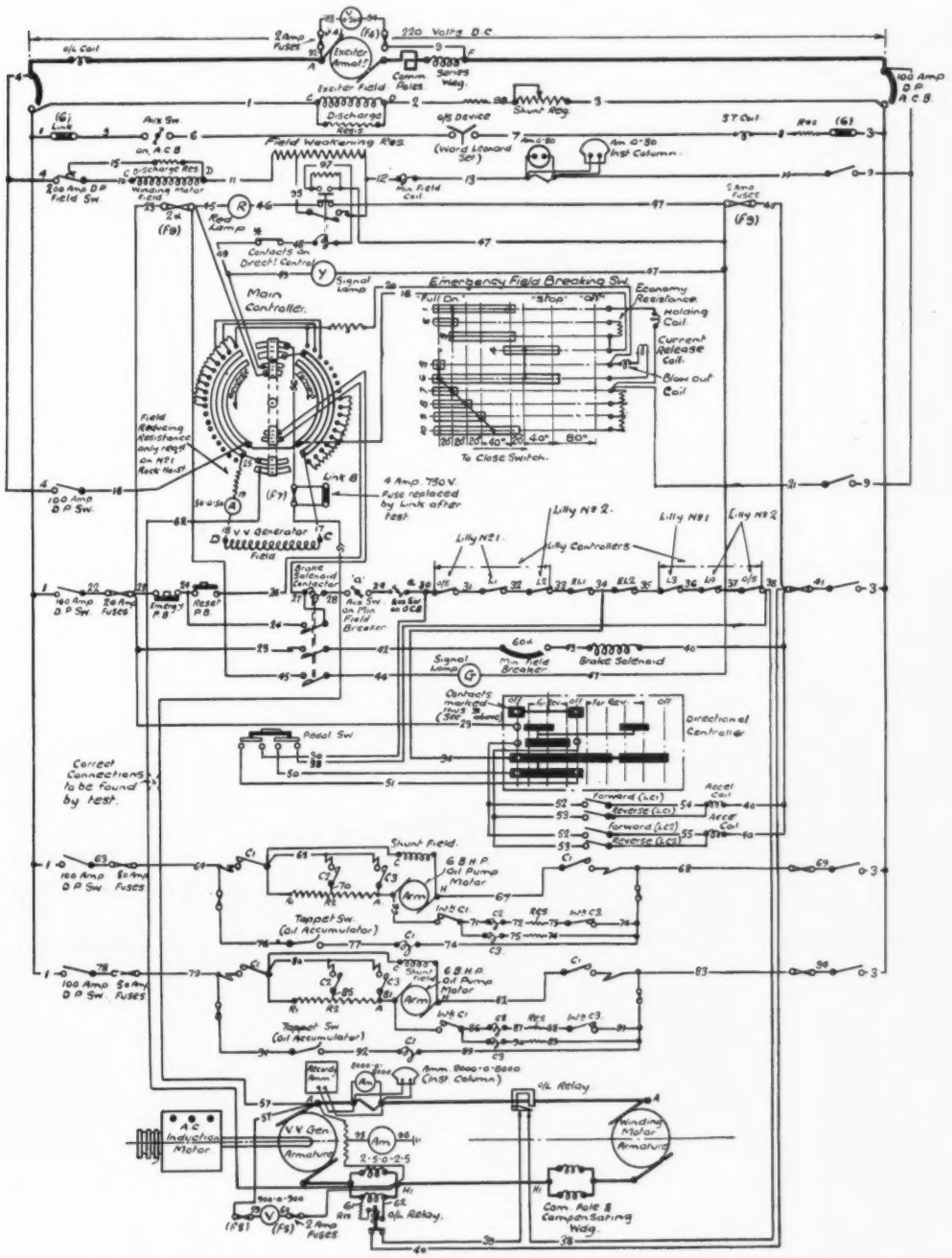


Fig. 12.—Schematic Diagram of Connections for control circuit of Ward Leonard winding equipment.

fails. In such a case the energy paid back to the converter set might overspeed the set to a dangerous degree unless effective means were taken to prevent it. To overcome this danger, an overspeed device is driven from the converter set and on the set reaching a pre-determined overspeed, the circuit of the exciter field is opened, thus cutting off the excitation of the winding motor and generator and destroying all possibility of energy being transmitted from the motor to the generator. At the same time the mechanical brakes are applied to bring the winder to rest. Overspeed protection of the winder itself is provided by a Lilly Controller "C" Model, which, in addition to overspeed, embodies overwind limit switches and also trips the emergency brake if retardation does not occur at a pre-determined distance from bank.

The mechanical parts of the two winders for East Geduld Mines have been supplied by Messrs. Fullerton, Hodgart & Barclay, Ltd., Paisley; each winder is of the double-drum type, each drum being 14 ft diameter by 6 ft wide. Both drums are loose on the shaft and fitted with clutches of the multi-tooth type. Space does not permit a detailed account of these items, but it will be appreciated that they are complete in every respect to meet the stringent regulations in force in South Africa.

An interesting occurrence in connection with the erection of the No. 1 Equipment is worthy of mention. The English Electric Company's Equipment was required to replace existing electrical equipment of another make, which latter was to be installed for the "Man" winder at No. 2 shaft. Owing to the intense activity in the gold mining industry, it was stipulated that the changeover must be done in one week end.

Previous to the appointed week end, the converter set had been erected on a new set of foundations and as much as possible of the cable work carried out. When the appointed time came, the changeover was completed within 48 hours, which, bearing in mind the size of the motors to be exchanged and the number of intricate cable connections to be made, was a notable erecting achievement.

Diesel-Electric Shunting Locomotives.

By L. H. SHORT, M.C, A.M.I.E.E., A.M.Inst.T., Assistant Manager Traction Department.

In the investigations which have been carried out in recent years to secure greater economies in railway working, considerable attention has been given to the shunting and marshalling yards in order to speed up the transit of merchandise, and at the same time to reduce the expense of handling this material.

Improvements have been made, notably by the re-alignment of tracks, by the provision of rail brakes, the adoption of containers and the standard waggon, and last but not least, by the improvement in type and form of the shunting locomotive. It is with this latter aspect that this article deals.

In a number of the large shunting yards in this country, working is on a 24-hour basis for 6½ days per week, and the problem which has confronted the railway engineer is to design a locomotive which will meet these conditions. It cannot be said that the steam locomotive without relief units can wholly meet these requirements, and attention is now being focussed on the diesel engined locomotive as a means of meeting the situation. The ideal characteristics of a shunting locomotive, can be stated as follows:—

1. Maximum availability.
2. Economy in working.
3. No stand-by losses.
4. Ease of operation and absence of noise.
5. Comfort of the driver.
6. Simplicity of inspection and maintenance.

The diesel locomotive can claim fairly to meet all these requirements, and by careful design and attention to detail, a locomotive can be built which has very definite advantages over a steam locomotive of similar weight. A great deal of investigation has been carried out as to the best method of coupling the diesel engine to the driving wheels, and in order to obtain comparative data one of the leading railway

Fig. 1.—300/350 H.P. Diesel-Electric Locomotive hauling Freight Waggons at Healey Mills Sidings, Wakefield. L.M.S. Railway.

companies in this country, now has in service ten diesel mechanically geared units, and two diesel locomotives fitted with electric transmission.

The English Electric Company have played their part in this investigation, as one of the two diesel-electric units is of the Company's design and manufacture. The Company was early in the field of diesel traction, and has manufactured locomotives and coaches with electrical and mechanical transmission. As a result of our experience, it is considered that for transmission of 200 h.p. and over, the electrical transmission is superior to any form of mechanical transmission.

The diesel-electric locomotive referred to above is a 300/350 h.p. unit, weighing 47 tons, in working order, and designed with a view to replacing a 6-coupled steam locomotive of the same weight. The locomotive is illustrated in the frontispiece, and Fig. 1, whilst Plate 1 shows the outline and general arrangement.

Reference has already been made to the ideal characteristics of a shunting locomotive, and it is, perhaps, interesting to note here how these requirements have been met.

Availability.

1. In the first place, availability to work for 23½ hours per day for 6½ days per week. This, in turn, requires reliability and to achieve this a medium speed "English Electric" diesel engine of the standard "K" type is used, developing 300 h.p. at 600 r.p.m., and 350 h.p. at 675 r.p.m. This engine is of a simple and robust design having a piston speed of 1,200 ft. per minute, and is provided with force-feed automatic lubrication throughout. Cast-iron pistons are fitted and there are two valves per cylinder.

The main generator is of substantial construction, with inherent overload capacity, and is direct coupled to the engine shaft. The engine and generator unit are shown in Fig. 2.

"Torque Control" is employed for the control of the electric transmission, and this is extremely simple and reliable in operation. This system of control has now been in operation for a number of years on both locomotives and motor coaches, and its particular features are that it permits full torque to be taken from the engine over the whole working range without overloading the engine at any point, at the same time the control of the speed of working of the locomotive is in the driver's hands. The ideal combination of manual control of the speed of working, with automatic control of the engine and generator loadings is thus obtained.

In the demonstration locomotive referred to above the fuel tanks are of 100 gallons capacity, but future engines will be fitted with 500 gallon tanks, which will enable all fuelling and watering to be carried out in the engine sheds during the weekly inspection period. The locomotive, therefore, has no need to leave the shunting lines, and relief engines are not required.

Economy in Working.

2. Economy of working is achieved through various channels. In the first place fuel and lubrication costs per hour average 1s., as compared with 2s. 0d. per hour of a steam locomotive. The amount of make up water required per 24 hour day is one or two gallons only. Shed duties are reduced to a minimum and take the form of a weekly inspection, there being no boiler fires to light and draw, and no ash pans to clean out. The locomotive is arranged so that when necessary it can be handled by one man on the footplate.

No Stand-by Losses.

3. One of the great assets of this new form of shunting unit is that it is available for duty at any time without special preparation. Electric starting of the diesel engine is employed and the push-button control for this purpose is mounted in the cab adjacent to the driving stands. The diesel engine is of the solid injection cold-starting type and under the worst climatic conditions it is started in a few seconds. As is well known, in a steam engine several hours are taken in lighting fires and raising steam before an engine is ready for service; this represents extra expense and loss of time in an emergency.

The faculty of immediate starting is of further advantage during shunting, as immediately there is a check in the shunting work the diesel engine is shut down so that stand-by losses are reduced to a minimum.

Ease of Operation.

4. In operation, the diesel-electric unit is extremely easy to handle, the control of the locomotive being centred in two small levers, a control and a reversing lever. The former controls the speed of working and the latter the direction of movement. The locomotive responds instantly to a movement of the control lever and reversing is carried out immediately, there being no need to take up a number of turns as on the reversing gear of a steam locomotive.

During intense shunting duty this quick working results in a very appreciable saving of time.

It is an interesting fact, that by the application of the tractive effort to the driving wheels by rotary motion, the diesel-electric locomotive of a given weight can transmit an effective tractive effort 10 per cent. to 15 per cent. greater than a steam locomotive of equal weight.

The lack of noise and absence of blowing off of steam and smoke are other contributory factors to the ease and safety of operation in the shunting yards, and it has been found that shunting operations are materially speeded up, particularly in windy and foggy weather as there is no pall of smoke and steam to obscure the shunters' signals.

Comfort of the Driver.

5. In the design of the diesel-electric unit it has been recognised that it is of the utmost

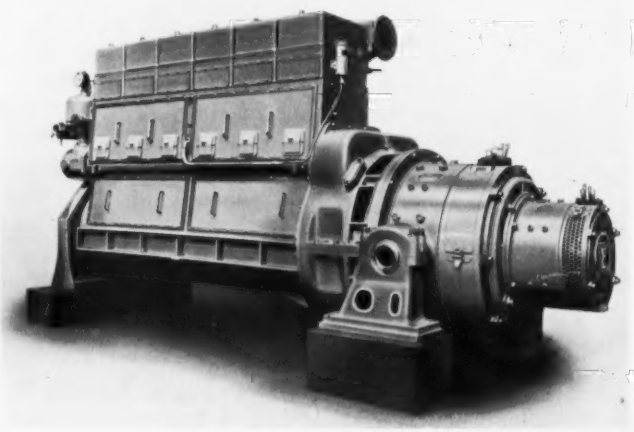
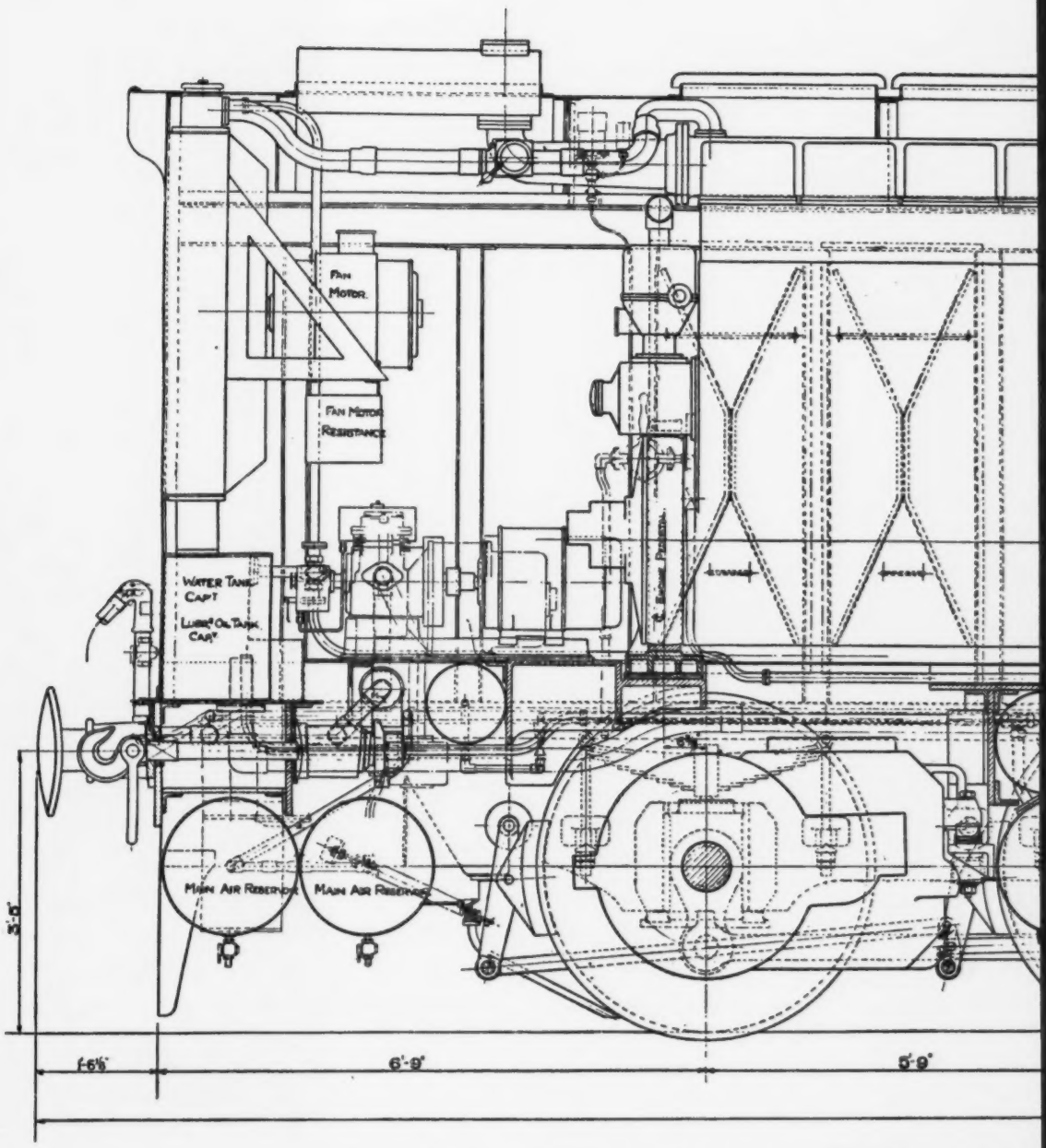
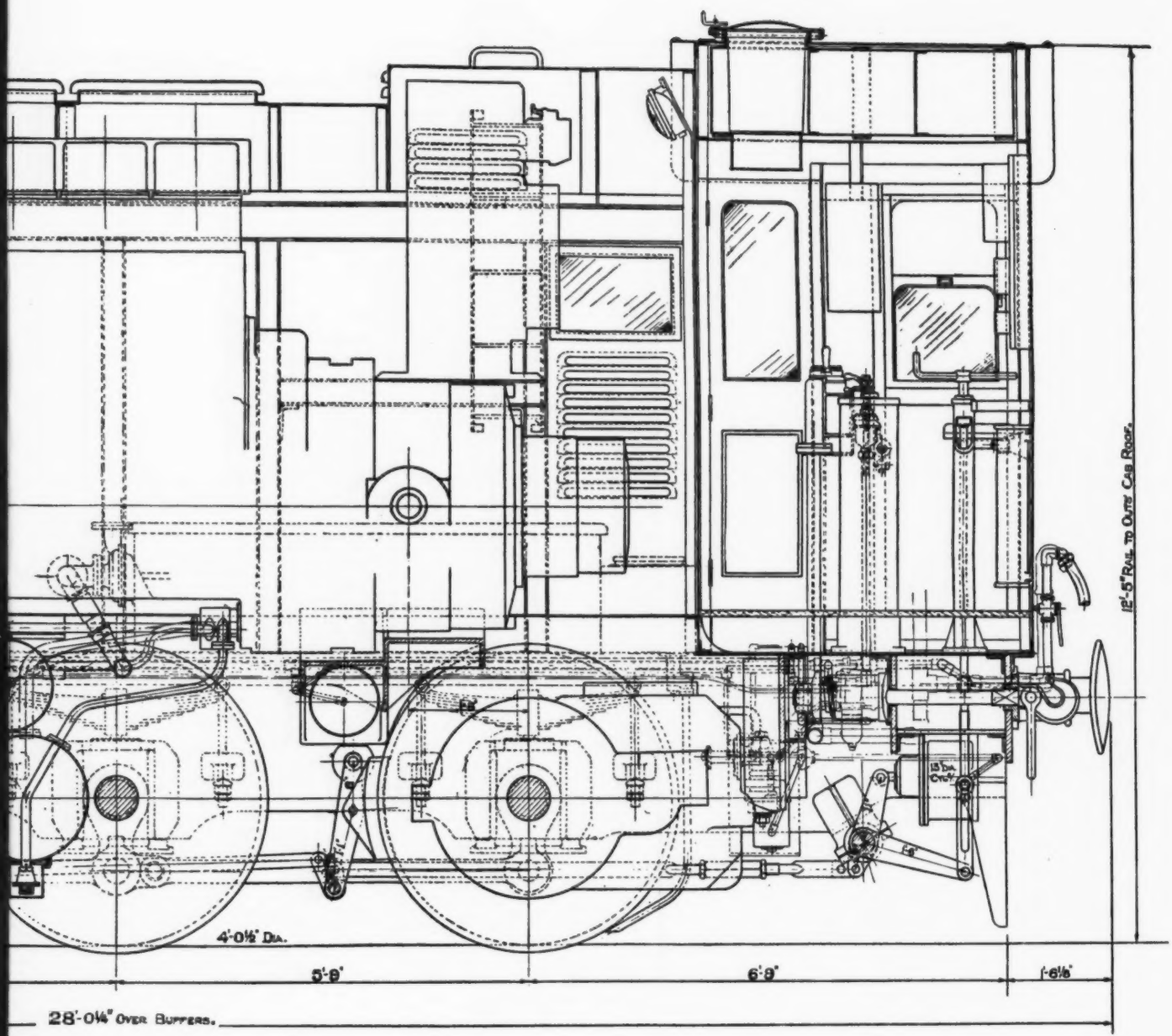


Fig. 2.—Engine and Generator Unit.



"English Electric"—"Ha

General Arrangement of 300/350 H.P. 47 To



...WTHORN LESLIE"

...N DIESEL-ELECTRIC LOCOMOTIVE

PLATE I

importance in the interests of safety and efficiency to arrange the locomotive so that the driver is able to attend to his duties with a minimum of fatigue, and maximum comfort.

The characteristics of the diesel locomotive are such that it is possible to arrive much closer to these ideals than with a steam engine. It will be recognised that the absence of the locomotive boiler permits the use of an enclosed cab. This is fitted with hot water heaters under control of the driver, a dual driving position so that the driver can operate his engine from either side, depending on the configuration of the shunting yard. Seats and arm rests are also fitted, and an electric hot-plate is provided for heating his meals.

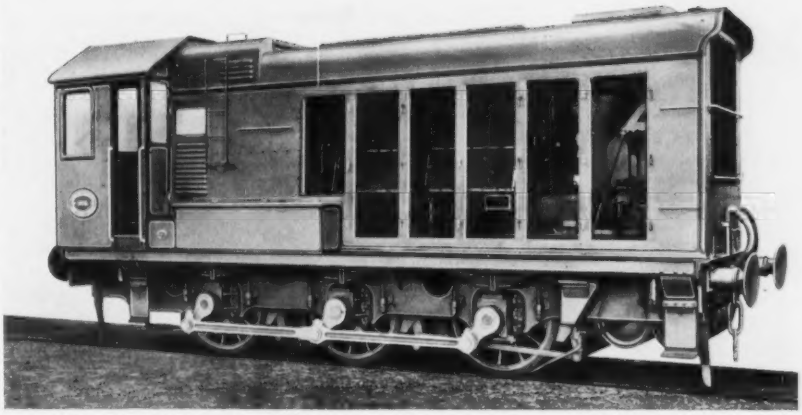


Fig. 3.—Diesel-Electric Locomotive with side-covers removed.

Fig. 4.—Interior of Driving Compartment.

There is no coal to handle, no soot or ash, and the improvement in working conditions has already been appreciated in the driver's home as his overalls now require less attention than formerly.

Inspection and Maintenance.

6. Lastly, but by no means of least importance, is the simplicity of maintenance of the diesel-electric locomotive. The layout is arranged so that all parts that require inspection are easy of access. A half day's work is sufficient to carry out the routine inspection which comprises, chiefly, cleaning of oil and fuel filters, inspection of Diesel engine valve gear, and electrical contacts and commutators.

In addition to direct access for inspection each main portion of equipment is arranged so that it may be removed easily from the locomotive should this be necessary for heavy maintenance purposes. Thus, the complete engine and generator set can be lifted straight out, as a detachable roof is fitted for this purpose; similarly, the main generator armature may be drawn out through the driving cab without disturbing the engine generator unit; in like manner the design provides for the removal of all other main items. A view of the locomotive with side covers removed is shown in Fig. 3.

Performance.

One of the advantages of electric transmission is its flexibility, and the two performance curves

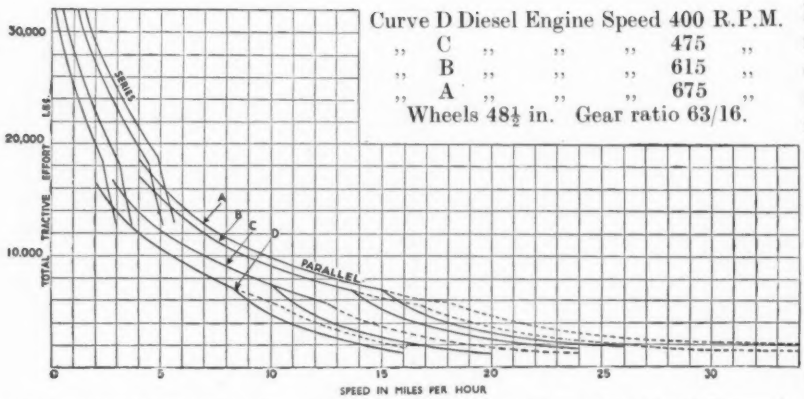


Fig. 5.—Approximate Speed Tractive Effort Curves of 300/350 H.P. Diesel-Electric Locomotive.

Illustrated in Figs. 5 and 6 demonstrate the working range of two different locomotives.

The curve shown in Fig. 5 illustrates the performance of a locomotive weighing 47 tons in working order. It will be noticed that the locomotive is capable of a tractive effort at starting of 30,000 lbs., up to smaller tractive efforts at 30 m.p.h. ; this particular locomotive can carry out the following duties :—

(a) Shunting and marshalling heavy freight trains up to 1,000 tons.
(b) Hauling freight trains of 400 tons in normal freight service.
(c) Maintaining a Branch Line Passenger service with trailing loads of about 100 tons.

Fig. 6 shows the performance of a locomotive designed for shunting duty only. The locomotive weighs in working order 54 tons, and has a starting tractive effort of 36,000 lbs.

Service Operation.

The locomotive illustrated in this article has been operating by the co-operation of the London Midland & Scottish Railway, on its lines since April, 1934, up to the present time. During this period the locomotive has been working on a 24-hour service for 6½ days per week, and has now completed some 4,000 hours in service, and regular shunting duties have been carried out in the following L.M.S. shunting yards:—Rugby; Crewe; Beeston Sidings, Nottingham; Toton Sidings, Nottingham; Camden, N. London; Salford, near Manchester; Healey Mills, Wakefield; Carlisle.

The service in the above localities has covered almost every type of shunting duty carried out on the railway, and the locomotive has been able to perform all the duties without any difficulty, and has proved itself, in availability, efficiency of operation and reliability, superior to the steam locomotive.

Reproduced below are extracts from the running log of the locomotive at three of the above yards.

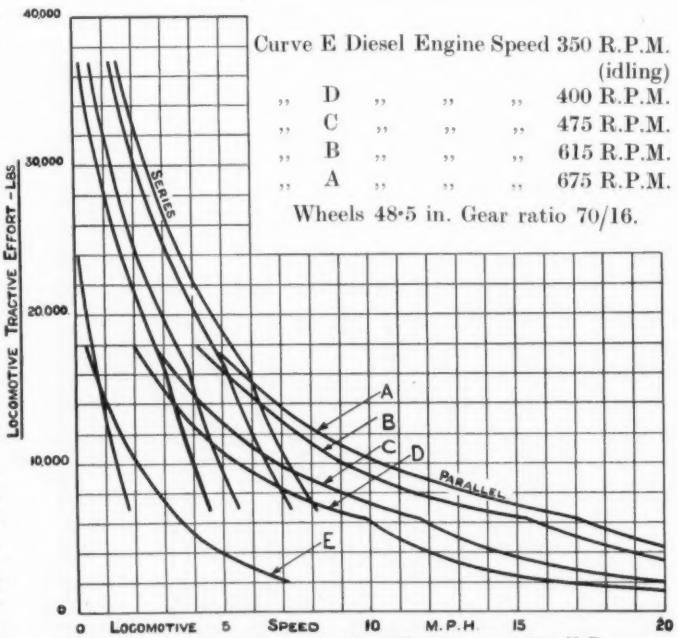


Fig. 6.—Approximate Speed Tractive Effort Curves of 350 H.P. Diesel-Electric Locomotive.

300/350 H.P. DIESEL-ELECTRIC LOCOMOTIVE. REPRESENTATIVE EXTRACTS OF RUNNING DATA FROM LOG BOOK.

Date Week Ending	Mileage.	Loco. Working Hours.	Engine Running Hours.	Engine Fuel Gallons.	Fuel Miles per Gallon.	Fuel Gallons per Hour Engine Running.	Lub-Oil Gallons.	Cooling Water, Gallons.
SHUNTING DUTY AT CREWE YARD L.M.S.								
28/4/34	178	109	99	247.5	.72	2.5	12.5	9
5/5/34	179	99.6	92.7	274	.655	2.75	7.5	5
12/5/34	199	109.25	99.75	306	.65	3.07	12.5	10
SHUNTING DUTY AT CAMDEN YARD, N. LONDON, L.M.S.								
14/7/34	225	151	126	317	.710	2.52	18	5
21/7/34	195	150	124	325	.60	2.62	18	3½
28/7/34	205	151	125	312	.658	2.5	21	4½
SHUNTING DUTY AT SALFORD YARD, NR. MANCHESTER, L.M.S.								
6/10/34	195	140	128½	309	.634	2.40	14	6
13/10/34	213	134½	120	310	.687	2.58	17	9
20/10/34	174	130	119	286	.610	2.38	16½	7½

Plate II shows an enlargement of the Teloc Chart for an actual day's shunting duty and may be taken as quite typical of the performance of this locomotive.

Actual engine running hours ...	20
Total number of movements ...	354
Total distance covered ...	44.5 miles
Average speed in operation ...	5.0 m.p.h.
Average weight of train hauled	110 tons
Maximum weight of train hauled	750 tons
Approximate total ton miles, including locomotive weight	7,000
Fuel consumption for 24 hours	52.7 galls.
Total lubricating oil consumption	2.5 galls.
Engine cooling water make up	1.5 galls.
Approx. ton miles per gallon of fuel	133

The duty comprised is hauling fairly heavy freight trains out of sidings up a gradient of 1 in 145, and then breaking up the train by shunting from the top of this gradient, and distributing the waggons into the various sidings below.

The portion of the chart which is marked "AB" represents a 750 ton train being hauled up the 1/145 gradient.

In addition to this duty, there were also a considerable number of movements on the level in moving and marshalling trains in the various sidings.

As an example of work in a hump shunting yard the following observations were made :—

The waggons are first hauled from the level up a 1/90 grade, and then shunted over a hump. The engine then runs a short distance light to pick up another rake of waggons.

The average load figures cover four trains being shunted per hour.

WORK DONE HAULING TRAINS FROM LEVEL SIDINGS TO HUMP :—

480 yards /shunt ... 255 tons.
=1,920 ,, /4 shunts ... 255 tons per hour
= 278.0 ton miles/hour.

SHUNTING OVER HUMP :

150 yards /shunt ... 150 tons (this figure taken as average weight of train during shunt)
=600 ,, /4 shunts ... 150 tons/hour
= 51 ton miles/hour

RUNNING OVER HUMP TO PICK UP AGAIN :

1,000 yards	... ...	47 tons per hour
		= 26.8 tons m.p.h.
Total	...	= 355.8 ton miles/hour

The average fuel consumption is approximately 2.5 galls. per hour, and consumption is 141.0 ton miles/gallon. When pushing waggons over the hump the following movements were observed :—

Average number of movements/hour 76
„ distance ... ... 23 feet

EXAMINATION OF UNITS AFTER SERVICE OPERATION.

After 3,000 hours running of the Diesel engine a favourable opportunity was taken to examine the mechanical and electrical equipment of the demonstration locomotive with very gratifying results. A brief résumé of this examination is given below.

The pistons and piston rings were in excellent condition. The cylinder liners showed negligible wear. The big-end bearings were carefully checked, and were found to have ·007″ clearance as originally set, the surface bedding was good, and the white metal bearings free from cracks or blemishes. The small-end bearings were in a similar condition, the bearings having retained their original clearance of ·004″.

The lubricating oil was chemically examined for dilution, and this was found to be less than 1½ per cent., and by analysis showed little change from the original. From the periodic examinations which have been made it appears that it will be unnecessary to change the lubricating oil as a whole, more often than once in 12 months' working.

Following the examination and as a result of experience in running, the following inspection periods have been arrived at :—

Detail.	Engine Running Hours.
Exhaust Valves regrinding	1,000/1,500
Suction Valves	2,000
Fuel Injection Valves ...	1,500
General overhaul Piston and big-ends examining, etc....	annually, say 5,000/6,000 hours

The electrical equipment was also examined in detail. The main and auxiliary generator and driving motor commutators were found to be in excellent condition showing no signs of flashing or sparking. The electrical contactors were also in good order and evidence showed that the two or three hours' weekly maintenance was adequate to maintain the apparatus in first class condition.

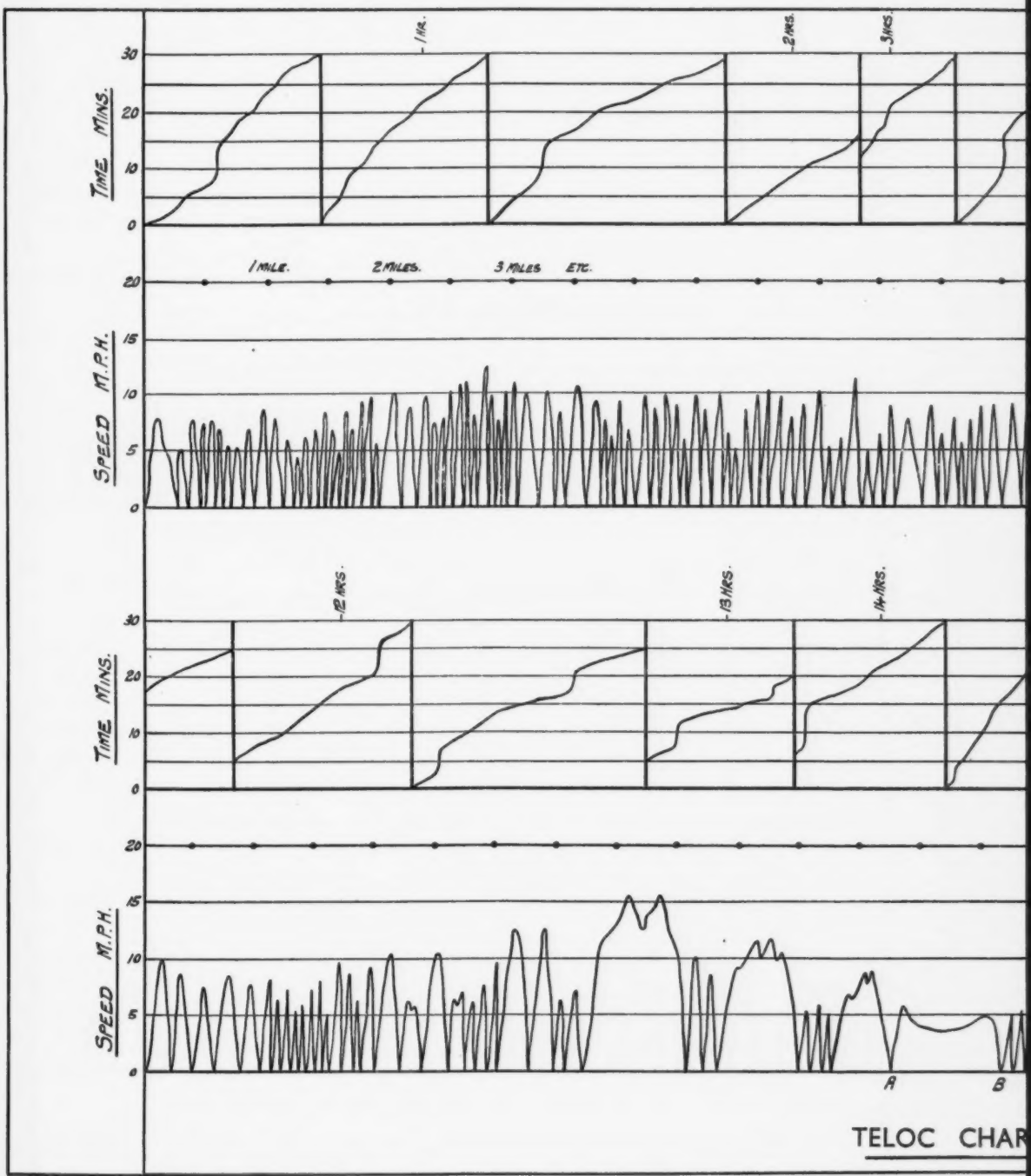
After the examination the locomotive was returned to service, and at the present time is in the Sheffield district operating in the various shunting yards in this area.

As a result of the successful tests carried out with the locomotive illustrated in this article, the Company were awarded at the beginning of the year an important contract by the London Midland and Scottish Railway Company for ten 350 H.P. Diesel-Electric Shunting Locomotives. These will be constructed in conjunction with Messrs. Hawthorn, Leslie & Company, who will supply the mechanical parts, the English Electric Company supplying the diesel engines, generators, driving motors and control gear.

From the foregoing it will be seen that the claim made for the diesel-electric unit to have an availability of practically 24 hours per day for 6½ days per week, has been thoroughly demonstrated. It will be appreciated that the testing period has been a particularly severe one, as during the whole time the locomotive has been in the hands of different drivers.

A further advantage provided by electrical transmission is that a steam locomotive driver is able to handle in service the diesel-electric unit after only two or three hours training. This feature is of particular value, not only in this country, but also to meet conditions obtaining abroad.

It is felt that no better testimonial can be made for the satisfactory operation of this diesel-electric locomotive, than the order which the Company has been awarded by the London Midland and Scottish Railway for ten similar 350 H.P. diesel-electric shunting locomotives. As in the case of the demonstration locomotive, these units will be constructed in conjunction with Messrs. Hawthorn, Leslie & Company.


TIME MINS.
30
20
10
0
1 HR.
2 HRS.
3 HRS.
1 MILE.
2 MILES.
3 MILES
ETC.
SPEED M.P.H.
20
15
10
5
0
TIME MINS.
12 HRS.
13 HRS.
14 HRS.
SPEED M.P.H.
A
B
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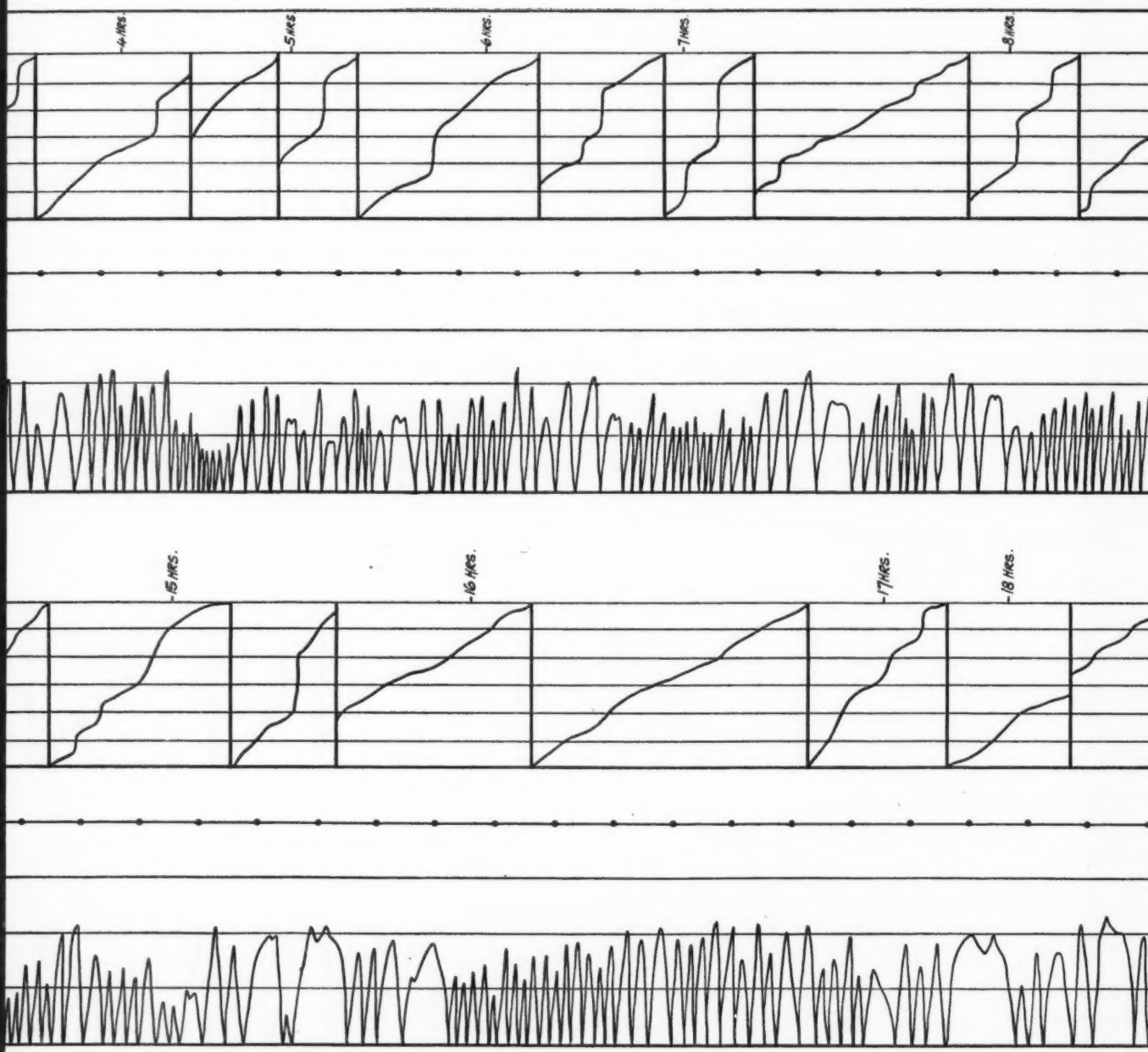


350 H.P. DIESEL - ELECTRIC SHUNTING LOCOMOTIVE

T FOR TYPICAL 24 HOURS DUTY SHIFT IN AN L.M.S. RAILWAY SHUNTING YARD

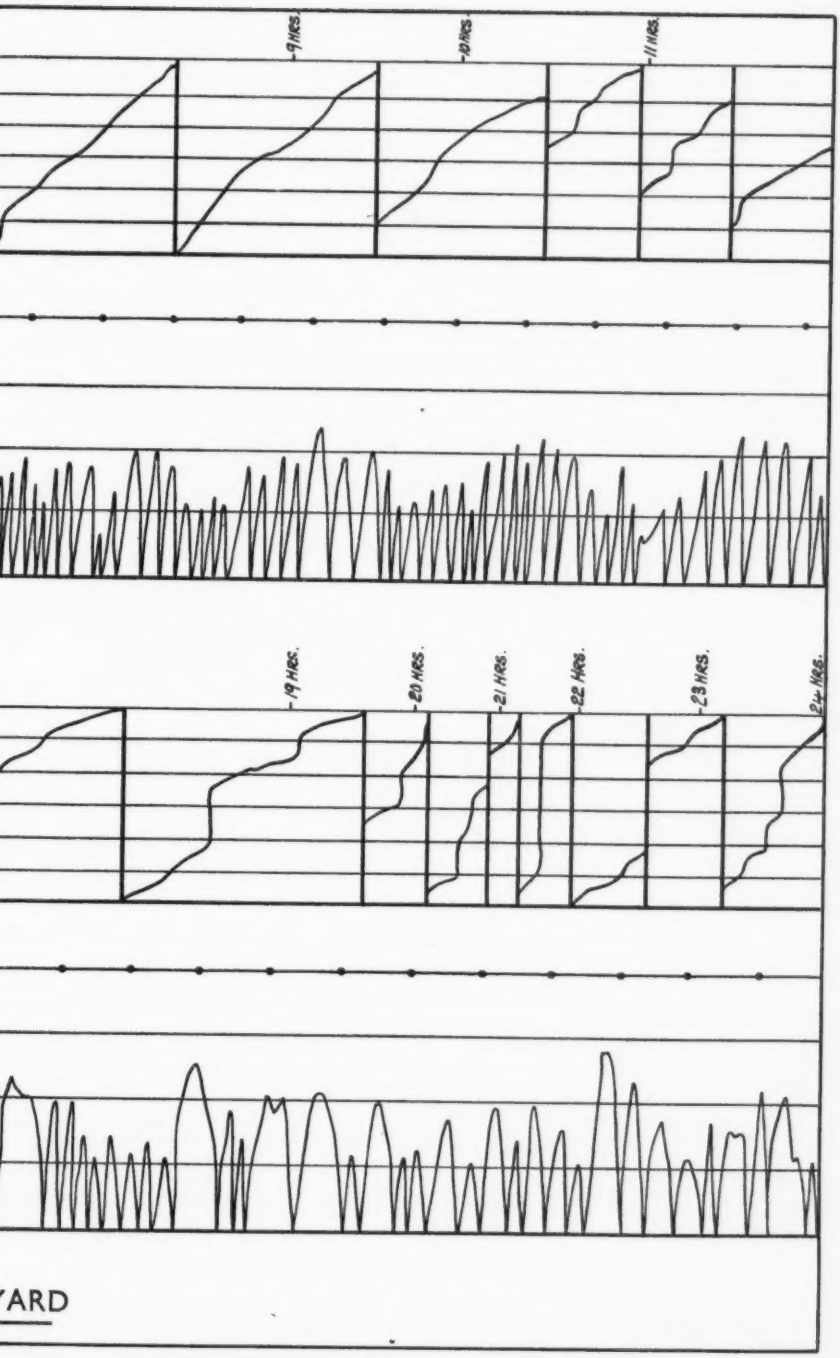
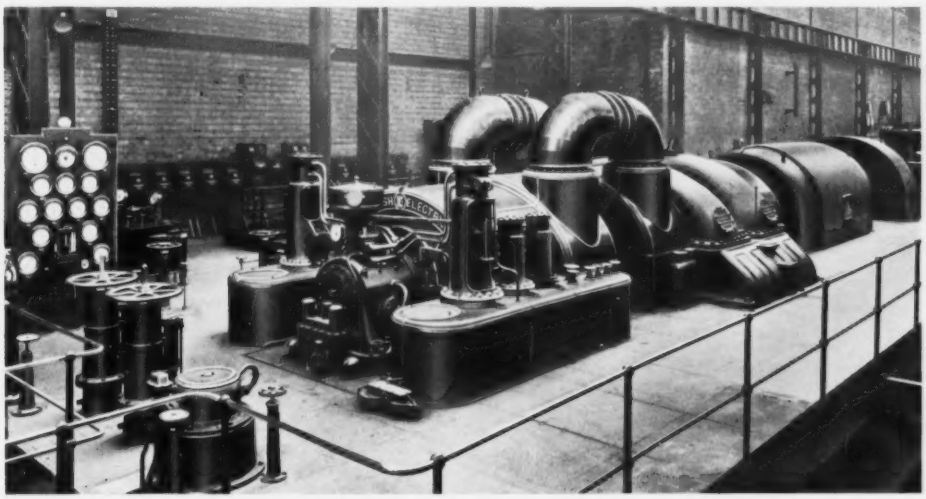


PLATE II

30,000 kW. Turbo-Alternator Set Installed at the Thornhill Power Station of the Yorkshire Electric Power Company.

By courtesy of the Yorkshire Electric Power Company we are able to give some interesting information relating to the performance of the 30,000 kW. Turbo-Alternator installed by the Company early in 1932. We preface this information with a brief description of the plant.



30,000 kW. Turbo-Alternator Set installed at Thornhill Power Station of the Yorkshire Electric Power Company.

The turbine is a two-cylinder unit, operating at a steam pressure of 415 lbs. per square inch, a temperature of 750 deg. F., and vacuum 28.85 in. The high-pressure rotor carries eighteen impulse stages, and each flow of the low-pressure rotors nine reaction stages. The high-pressure rotor is in one piece, the shaft and wheels being machined from a solid forging. The blades of nickel-steel contain 3 to 5 per cent. of nickel. The low-pressure rotor wheels are shrunk on to the shaft, and are fitted with mild-steel blades which have special manganese-steel inserts where subject to erosion.

Steam is passed from the turbine at four stages to heat the feed water on its way to the boiler, and the overall efficiency of the plant thereby increased.

Relays are fitted to the turbine to limit the pressure to which the cylinders would be subject in the event of the area of the steamway through the nozzles or blading being accidentally reduced.

A single surface condenser is suspended directly from the exhaust branch of the low-pressure turbine, the weight being relieved by springs, which will permit of slight relative movements. The condenser is fitted with a divided water-box and control of the circulating water is provided so that one-half of the cooling surface may be cleaned and inspected without interference with the operation of the machine.

The turbine drives an alternating current generator having a maximum continuous output of 30,000 kW., at a pressure of 10,500 volts, 3-phase, and frequency of 50 cycles per second.

The alternator is ventilated on the closed-circuit principle, air is forced through the machine by a turbo-blower driven from the outer end of the alternator shaft through reduction gearing, giving the blower a speed of 1,500 r.p.m.; the exciter is also run at this lower speed.

The air is cooled in its passage through the foundation blocks by three gilled-tube coolers, one supplied with cold condensate, and the others with river water.

By the use of condensate for the first cooler some heat is recovered which would otherwise be lost, and, in addition, that section of the cooler remains permanently clean.

Performance Figures.

From April, 1932, until July, 1934, the plant had been on load for 16,638 hours, and had generated 354,455,500 units; the average load on the machine during this period of 28 months was 21,300 kW. It is normally run for many months without stopping, and on the occasion of a recent visit of one of the Company's Engineers it had completed 17 weeks of continuous running.

The efficiency of the Thornhill Power Station is given in the Electricity Commissioners' Returns for the year ending 1933 as 25.42 per cent., which is the fourth highest for the whole of England and the highest for Group "B" Power Stations. This includes, however, the effect of the operation of the older and less efficient sections of the Station, which operate at a lower steam pressure. These machines are regularly used to deal with peak loads, and the efficiency of the high-pressure section of the Station alone over the last year has been 27 per cent.

Remote Supervisory Control of Switchgear.

By S. E. NEWMAN, A.M.I.E.E., and R. T. LYTHALL.

The Authors desire to acknowledge the courtesy of Messrs. Siemens Bros. & Co., Ltd., Woolwich, in supplying information and illustrations incorporated in this article.

The advantage of centralised control of a number of switching stations from a single control point is well recognised. The one factor which has prevented the more common use of this system in the past has been that of cost of pilot cable, particularly where distances between stations and control point are great. It is clear that, given unlimited pilot cables, the necessary operations can easily be carried out, but at prohibitive cost.

Fortunately, automatic telephone apparatus has reached such a high degree of development, that it is now possible to provide a system of remote control with a small number of pilots, in many cases as few as two.

It will be appreciated that "remote control" may include many other functions besides those of opening and closing of circuit-breakers, such as :—

(*a*) Starting and stopping of machines, opening and closing valves for hydraulic work.

(*b*) Raising and lowering voltage or speed.

(*c*) Indication of control operations, alarm devices, etc.

(*d*) Selected meter readings, including verification of synchronism, actual synchronising, transformer tap change position indication, water level, or gate position indication, etc.

(*e*) Continuous meter readings.

(*f*) Telephonic communication.

As an example of the foregoing, it is of interest to set out briefly the various functions accomplished by a remote control system recently completed at a large switching station near Birmingham for the Shropshire, Worcestershire & Staffordshire Electric Power Company.

In this station there are two large metal-clad switchboards, one on the 33 kV. system, and the

other on the 5.5 kV. system, the boards are illustrated in Figs. 1 and 2 respectively.

The remote control apparatus installed covers the following functions :—

(1) Close and open 27 circuit-breakers including neutral breakers.

(2) Indicate the position of 34 circuit-breakers including neutral breakers.

(3) Indicate the position of busbar selective devices on 23 circuit-breakers.

(4) Control and indicate the positions of the 15 tappings on each of the two transformers.

(5) Provide controls for obtaining a check of synchronism.

(6) Indicate, by selection, ammeter readings on 23 circuits.

(7) Indicate, by selection, eight voltmeter readings, four on 33 kV. and four on 5.5 kV. circuits.

(8) Telephonic communication.

A second station similar to the above except for small differences in the number of circuits, is also controlled from the same point. A study of the functions shows the advantages to be gained by centralised control, and, within certain limits a number of stations may be controlled either in series disposition or radial, (see Fig. 3) or a combination of both.

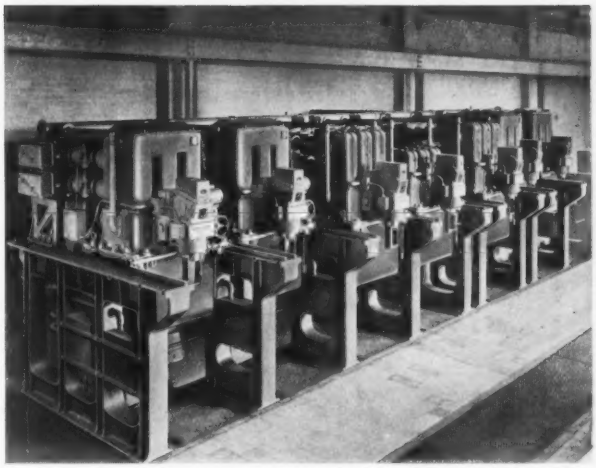


Fig. 1. 33 kV. Switchboard arranged for Supervisory Control.

There are a number of forms which remote supervisory control may take. Some of these are of a special character, such as the carrier current, and medium and audible frequency types. The more common forms are known as the coded impulse type, and the synchronous type. Of these latter, the coded impulse type

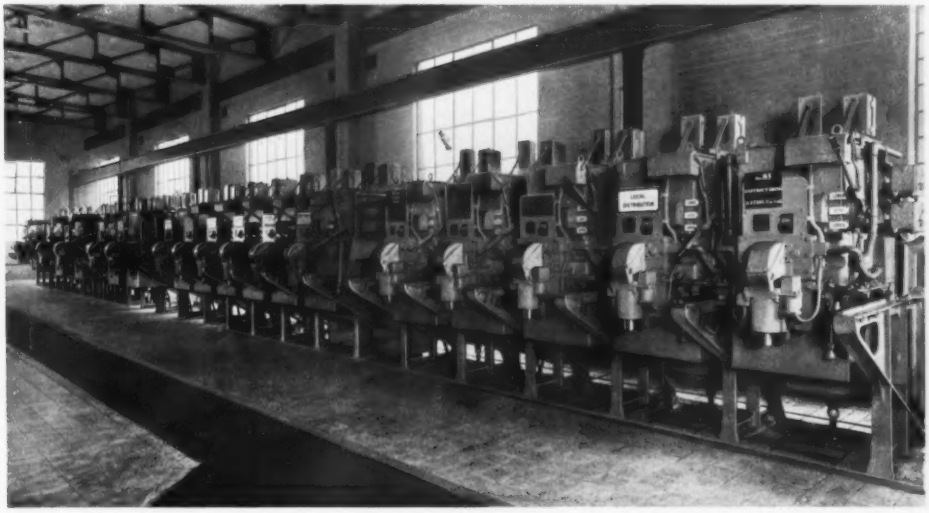


Fig. 2. 5.5 kV. Switchboard arranged for Supervisory Control.

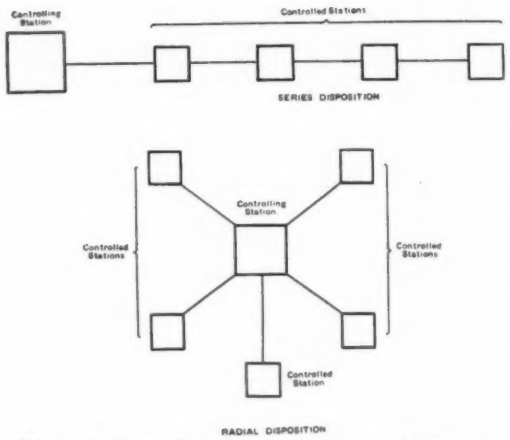


Fig. 3. Diagram illustrating Series and Radial Control.

is almost universally used in this country, while both coded and synchronous types are common in America.

In the present article, the description is limited to the coded impulse type, although it should be borne in mind that in all forms, the results achieved are the same, but by different methods.

The coded impulse form of control is based on the general principles employed in automatic telephone work, and in the particular system illustrated in this article four pilots are employed. Advantage is taken of the fact that the pilot wires are not in continuous use, and the equipment provides the means of associating any one piece of apparatus at one time with the pilot wires. This selection is accomplished in the same way as that used in automatic telephone work, by " steppers " referred to later, which are actuated by the impulses in such a way that the contact arms are moved round the same number of steps as there are impulses given to the circuit. By variation of the number of impulses, selection is made of as many contact points as are available. This principle is illustrated in Fig. 4.

For the generation of impulses, a special form of impulse generator is used, the moving parts of which are confined to two relays.

In the particular system illustrated two stages of selection must be completed before an executive impulse for a control signal is given. The first is that of the controlled station, and the second that of the required operation.

In each controlled station two steppers are provided known as " substation marker " and " operation marker," and for the purpose of selection two trains of impulses are sent out from the control point. The equipment is so arranged that all the " substation markers " in the system respond to the first train of impulses sent out, but the " operation markers " only respond in the selected station to the second impulse.

The foregoing having been accomplished, and the " operation marker " in a selected station being ready for functioning on the operation performing relay, a signal is transmitted direct to the control point which confirms the selection. At this stage the executive or operation pulse may be given which completes the operating circuit for the selected relay by means of a wiper and contact on the " operation marker."

It will be noted that confirmation of a selection must be obtained before a final operation can be performed. While in actual practice the percentage of " wrong numbers " obtained in automatic telephone working is extraordinarily small, it is apparent that the consequences of a wrong selection in the case of remote control equipment might be disastrous. Steps are therefore taken to ensure against this by means of a check-back. In all systems this check is given, but the methods adopted may differ.

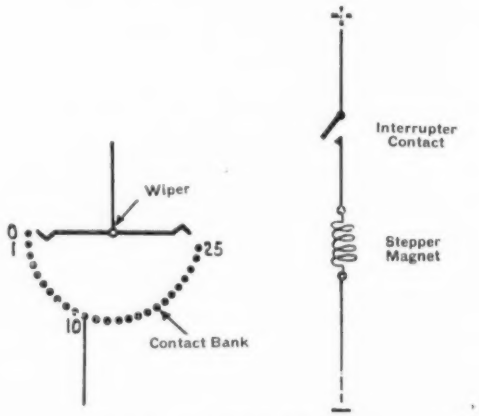


Fig. 4. " Stepper " Principle.

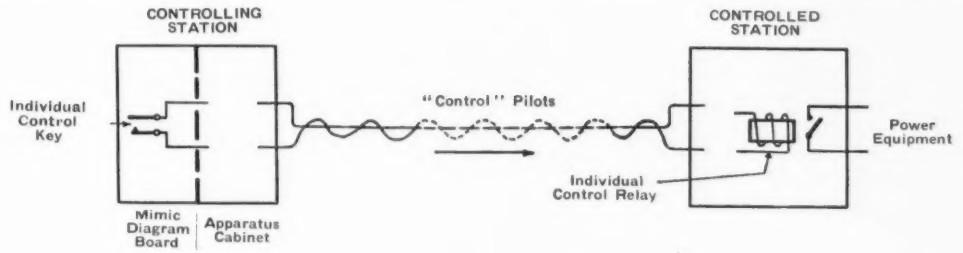


Fig. 5. Ordinary Control Signal.

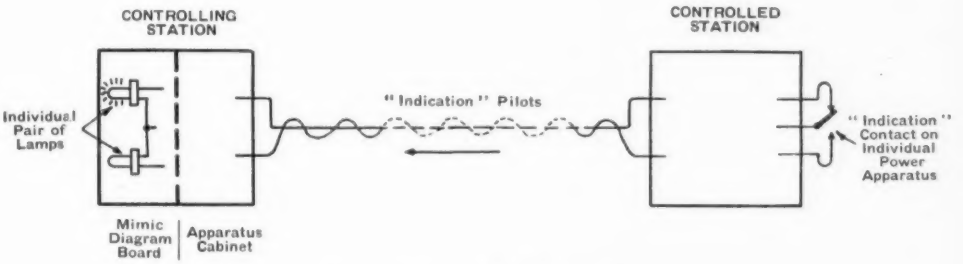


Fig. 6. Ordinary Indication Signal.

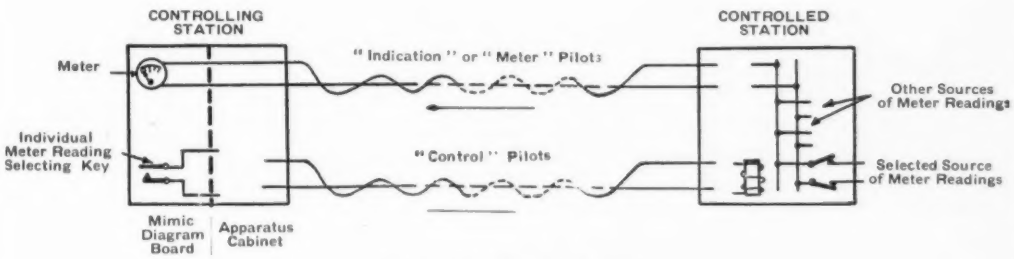


Fig. 7. Selected Meter Reading.

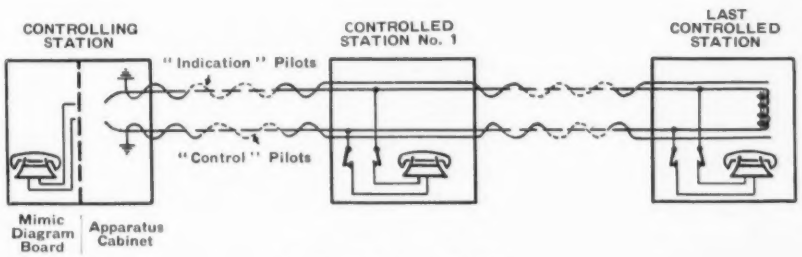


Fig. 8. Telephone Working.

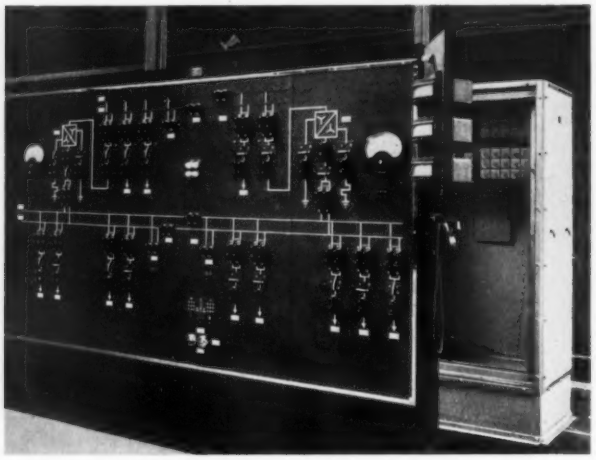


Fig. 9. Typical Control Board showing Mimic Diagrams, Control Switches and Indicators.

Fig. 5 shows diagrammatically the main connections used for the opening or closing operation of an oil circuit-breaker. With each circuit-breaker controlled, two relays are required, one to close and one to open it. A control operation is carried out by selecting, at the control point, which of these two relays is to be energised.

The indication signal is similar in general principle to the control signal, and identifying impulse trains are sent from the controlled station to the control point over the pair of pilots used for this purpose. Means are provided for signal storage in case two or more stations signal simultaneously and in this circumstance the signals are stored and transmitted in turn, one after the other.

It is essential at the control point, to know the condition (open or closed) of the circuit-breakers, isolating switches, and selector switches. In general, each supervised item is represented at the control point by some form of indicator, usually red and green lamps, or an indicator in a mimic diagram. Fig. 6 shows the circuit normally used for such indication, the impulse for which is given by means of a contact device on the actual apparatus controlled. As control and indication are carried out on separate pilots, they proceed simultaneously without mutual interference.

In many cases, it is essential that the Engineer at the control point should be able to ascertain the electrical conditions as to current, pressure or frequency from any source in a controlled station. In general, only one reading can be made at one time, and at the control point a number of selector switches are provided, by means of which a reading is selected and the appropriate meter is connected to the selected source at the controlled point. It is interesting to note that such readings as transformer tap positions, synchronism checks, and synchronising functions can be obtained.

In the case of the contract referred to earlier, a check on synchronism was provided. The apparatus to effect this consists of a synchro-verifier at the controlled substation, and a lamp at the control point. The synchro-verifier is

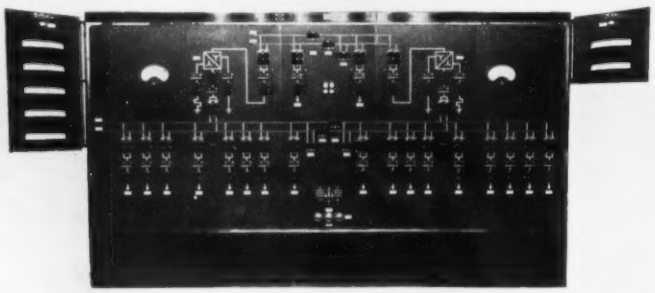


Fig. 10. Another Typical Control Board.

Fig. 11. Control Unit.

connected to two selected potential transformers, and makes contact only when the two supplies are in synchronism, and in this event, lights the lamp at the control point. Should the supplies differ slightly in frequency, the lamp flickers at a frequency equal to the difference. On the other hand, if there is an excessive frequency the lamp does not light.

The selection of the potential transformers for connection to the synchro-verifier is carried out by selector keys at the control point. The potential transformer directly associated with the particular oil circuit breaker to be closed is automatically selected when selecting the breaker for closing. The other potential transformer is selected at will by use of the appropriate key.

It will be clear that it is possible to go even further than a synchronism check and carry out actual synchronising at the control point by providing remote control of voltage and speed.

Fig. 7 shows the main connections necessary for the taking of a selected meter reading. These readings are normally taken over the indicator pilots and any indication signals arising during a period when meter reading is taking place, are stored until the pilots are free. This condition may be avoided by the use of separate pilots for meter reading, but such a procedure is not often warranted.

Facilities are provided for communication between all points on the controlled system. Fig. 8 shows the telephone connections between a control point and two controlled stations.

In the foregoing, a description has been given of the types of control and the various functions accomplished.

The equipment necessary for this consists of :—

At the Control Point.

Control board with or without diagram.

Equipment cabinet.

Battery and Charging Plant.

At the Controlled Points.

Equipment cabinet.

Battery and Charging Plant.

An outline has already been given of a typical installation for the supervisory control of 33 kV. and 5.5 kV. switchgear. Figs. 9 and 10 show the control boards associated with this installation.

It will be noted that the whole of the main electrical connections can be seen at once from the mimic diagram built on to the face of the board. Indicating lamps provide means of showing the state of each circuit, while the illustration clearly shows the indicating instruments for remote reading, and in Fig. 9 an

equipment cabinet and telephone can be seen on the right hand.

The control unit, mounted in the various mimic circuits, is shown in Fig. 11. The pointer on this unit is capable of being moved through 90°, and, being the same width as the mimic diagram circuit line, forms either a continuation of that line or completely breaks the continuation when at right angles, thus a clear indication is given of the last operation performed. A small lamp is provided to light up when signalling is in progress, and a press-button is used for acknowledging signals.

Apart from such details as fuses, terminal boards, etc., the remaining equipment consists almost entirely of "steppers" and relays.

The "stepper" is a magnet and ratchet operated device having a number of arms which can rotate around a bank of contacts. Operation of the arms is by means of current impulses in the magnet. A typical "stepper" is shown in Fig. 12. While Fig. 13 illustrates a typical relay, which, in view of its important duty, is very sturdily built, and has an efficient magnetic and mechanical design. Double contacts are employed for reliability.

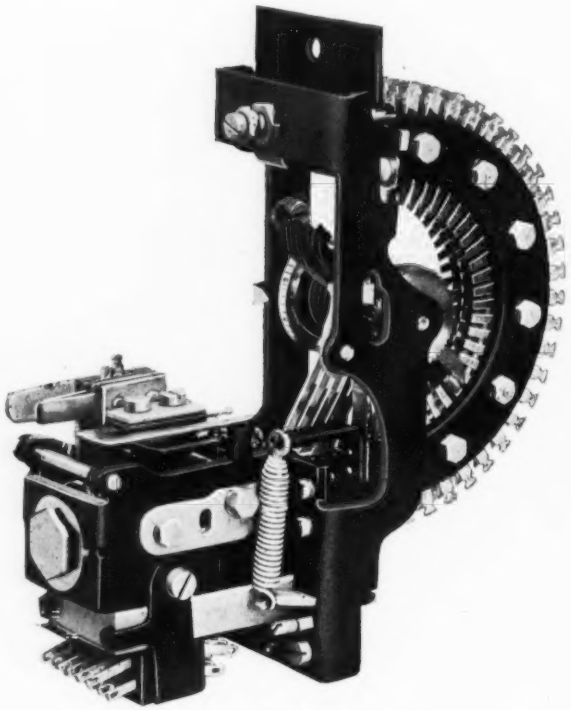


Fig. 12. A Typical "Stepper."

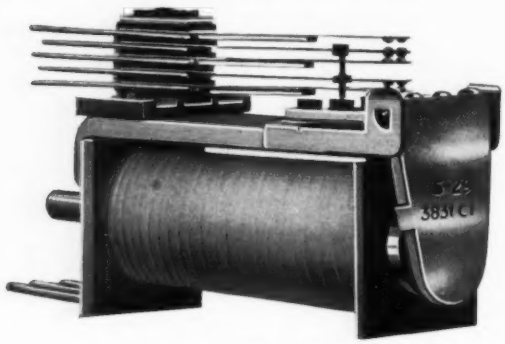


Fig. 13. A Typical Relay.

Normally the system described operates on 50 volts D.C., and, in order to provide a definite source of constant potential, a small battery is usually employed.

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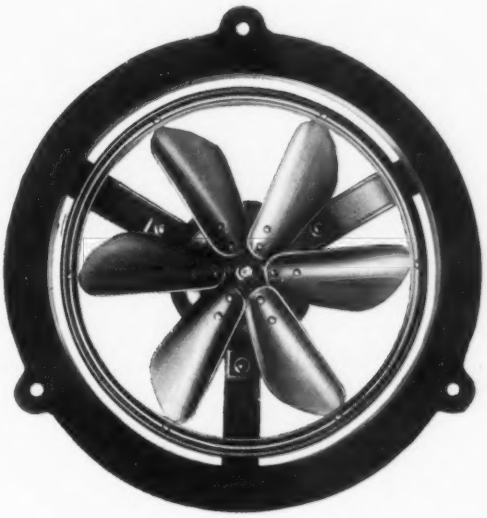

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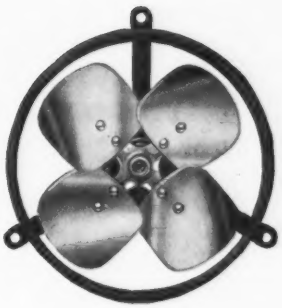

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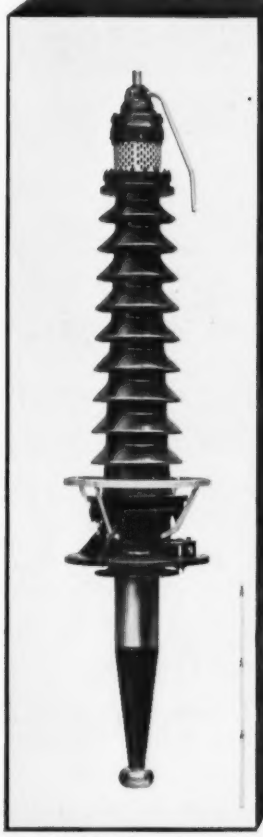

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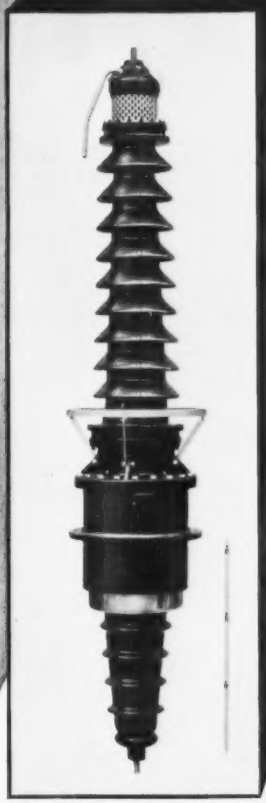

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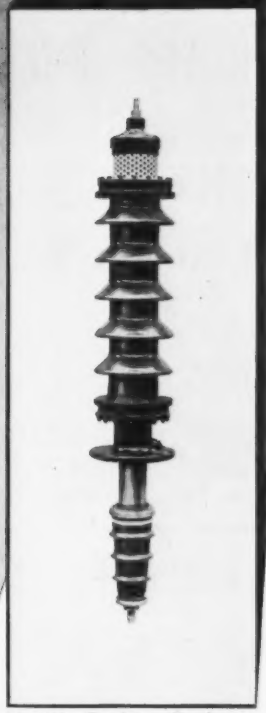

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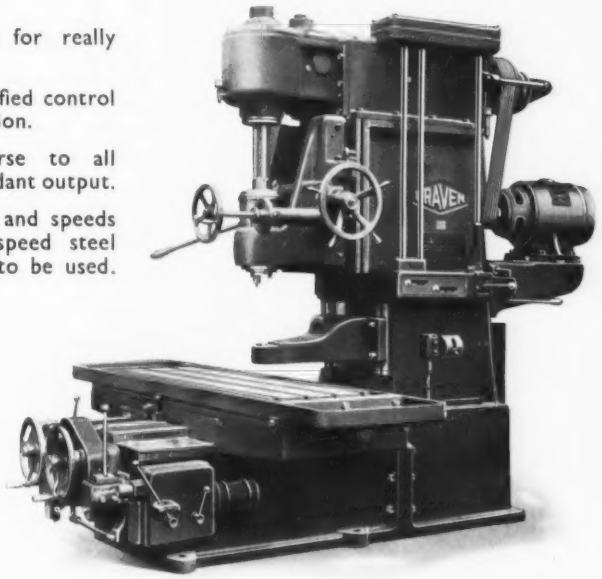

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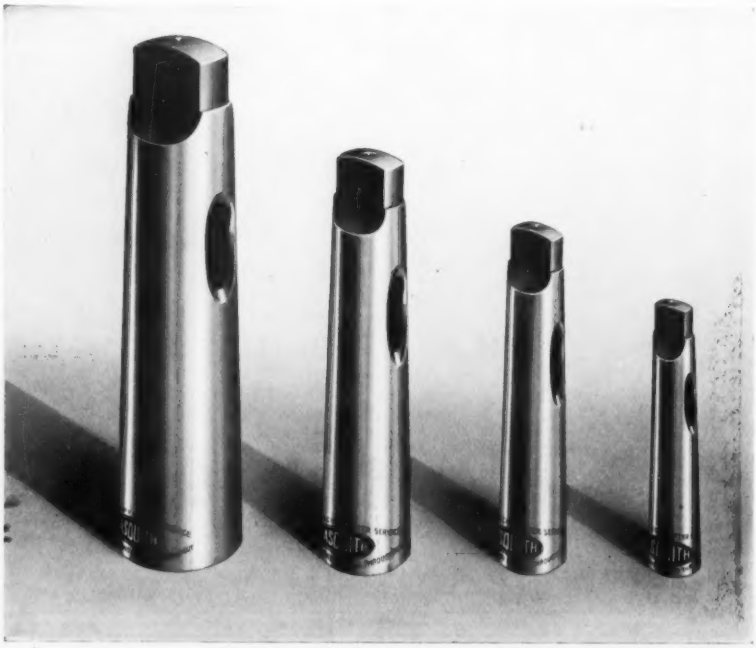

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